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# AIR QUALITY MONITORING STUDIES IN THE SUDBURY AREA 1978 TO 1988

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# 1978 TO 1988

Report Prepared By:

Technical Assessment Section
Northeastern Region
Ontario Ministry of the Environment

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# IN THE SUDBURY AREA

# 1978 TO 1988

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# 1. EXECUTIVE SUMMARY

In the Sudbury area, sulphur dioxide ($SO_2$) has been the air contaminant of most concern since the Ministry began its routine monitoring in the early 1970's. During the period from 1978 to 1988, the data indicate that the air quality in Sudbury, specifically for $SO_2$, has been gradually improving, especially during recent years. Significant reductions in short-term $SO_2$ episodes have resulted from several factors, such as changes in the smelting process at Falconbridge Ltd. in 1978 and the implementation of the Ministry-imposed "Supplementary Control Program" for Inco Ltd. in 1978, and for Falconbridge Ltd. in 1984. The latter was designed to reduce $SO_2$ episodes through production curtailments during adverse dispersion conditions in order to meet a "control limit" of 0.50 ppm $SO_2$ averaged over 1-hour. This limit, however, continues to be exceeded from time to time such that improvements are required in the control of $SO_2$ emissions from area smelters during periods of poor dispersion. Annual sulphur dioxide levels at most monitoring stations have remained relatively constant from 1978 to 1988, while a few stations were observed to have a decreasing trend. In comparison to previous years, ie. prior to 1978, annual $SO_2$ levels were relatively lower. The Provincial annual objective was marginally exceeded only once, occurring in 1979 at the Happy Valley $SO_2$ monitoring station.

As in previous years, ambient levels of the other air contaminants monitored, such as ozone ($O_3$), total reduced sulphur (TRS), suspended particulate (COH), carbon monoxide (CO), and oxides of nitrogen (NOX), were generally low and well within the annual Provincial objectives.

Carbon monoxide, nitrogen dioxide, and ozone have been monitored at 2 locations in Sudbury (Ash Street and Science North). Annual levels of these contaminants were generally low in comparison to levels measured in other urban centres in the province. Higher levels for all 3 contaminants were observed at Science North as compared to Ash Street. This difference is felt to be a function of location and the greater volume of traffic (automobile emissions) near the Science North monitor. Ground-level ozone concentrations were observed to exceed the 1-hour objective during the summer months. Pollution roses and trajectory analysis indicate that most of the ozone measured in Sudbury is a function of long-range transport originating from southern sources.

Annual suspended particulate (COH) levels in Sudbury were low in comparison to other urban centres in the province and have remained relatively constant from 1978 to 1988.

There are no significant sources of TRS in Sudbury and the Provincial objective has not been exceeded since monitoring began at the Science North complex in 1984. On occasion, low concentrations of TRS have been measured and meteorological conditions indicate the E.B. Eddy Forest Products kraft pulp & paper mill in Espanola as the probable source.

Total suspended particulate (TSP) levels in and around the Sudbury area showed a significant decrease after 1980. These reductions can be attributed to a combination of the following factors: firstly, decreases in particulate emissions from Inco and Falconbridge smelting operations in conjunction with an overall decrease in $SO_2$ emissions; secondly, decreases in particulate emissions from the 194 meter stack as a result of additional pollution controls and the decommissioning of the two 45 meter stacks at the pelletizing plant located at Inco's nickel-iron refinery complex; and thirdly, decreases in wind blown soil and tailings due to successful revegetation efforts and programs throughout the Sudbury area. Annual TSP levels at all locations were well within the Provincial objective. The 24-hour Provincial objective was marginally exceeded on occasion at all locations. Concentrations of copper (Cu), nickel (Ni), iron (Fe), and lead

(Pb) in total suspended particulate were also generally low and well within the annual objective, except for nickel concentrations, which on occasion, were found to be elevated near the Copper Cliff smelter.

Dustfall levels periodically exceeded the monthly and annual objectives and fluctuated yearly from site to site. Levels at each site were a reflection of local particulate sources. Improvements during recent years through abatement programs, revegetation and land reclamation efforts have reduced dustfall levels thereby allowing the decommissioning of most of the dustfall network.

From 1978 to 1983, the advisory level of 32 of the Air Pollution Index was exceeded on 7 separate occasions; once at Ash Street, 4 times at Coniston, and twice at New Sudbury. Since 1983, the advisory level has not been exceeded.

The Air Quality Index (AQI) system operating at the Science North complex in Sudbury was implemented by the Ontario Ministry of the Environment in June of 1988. A summary of the data collected indicates that air quality levels in the good to very good ranges in 1988 prevailed 98% of the time. The remaining 2% of the time, levels were in the moderate and poor range, predominantly due to ozone and sulphur dioxide.

## 2. INTRODUCTION

This report summarizes the air quality data collected by the Ontario Ministry of the Environment ambient air monitoring network in the Sudbury area from 1978 to 1988. As part of the province-wide air quality assessment program, the Ontario Ministry of the Environment has conducted routine monitoring in the Sudbury area since the early 1970's. The objective of this program is to monitor levels of air contaminants and to control anthropogenic (man-made) emissions that may adversely affect human health, animal life, sensitive vegetation and the normal use and enjoyment of property. For this purpose, ambient air quality objectives are set and to achieve these objectives, sources of pollution are identified, their emissions evaluated and appropriate control measures instituted. These surveys not only identify specific sources but also help to ensure that control measures have been successful and that sources are in compliance with air quality objectives, standards, provisional guidelines and control order requirements.

In the Sudbury region, the air contaminant of greatest significance is sulphur dioxide ($SO_2$), with Inco Ltd. and Falconbridge Ltd. smelters as the principal sources. Changes in the smelting processes and emission characteristics for both operations have necessitated changes in the ambient $SO_2$ monitoring network. Several new stations have been commissioned , while others have been discontinued and/or relocated since 1978. Monitoring in Sudbury is mostly conducted in urban areas and near industrial sources of air pollution. In addition, some stations were established to monitor the background air quality to determine compliance with air quality objectives and to observe trends in air quality.

In 1988, the Ministry commissioned its province-wide Air Quality Index (AQI) system which is an extension of the historical

Air Pollution Index (API) system. It provides real-time information on air quality for the 6 most common urban air contaminants. An AQI station was commissioned in Sudbury at the Science North complex.

## 3. MONITORING NETWORK

During the period 1978-1988, the Ontario Ministry of the Environment operated a network of ambient air monitors in the Sudbury area as listed in table 1 and shown in figures 1 and 2. These sites were located in areas to best measure the industrial impact on local air quality on the basis of population distribution and prevailing wind patterns. Two types of air contaminants are routinely monitored in Sudbury: gaseous contaminants and particulate matter. Gaseous contaminants include: sulphur dioxide, oxides of nitrogen, ozone, carbon monoxide and total reduced sulphur. These pollutants are measured by continuous analyzers. Particulate matter is measured as dustfall, total suspended particulate (TSP) and soiling index (COH). Meteorological data (wind speed, wind direction and temperature) are also an integral part of the network and are obtained from two stations in the Sudbury area.

The method of operation of the instrumentation used is briefly mentioned throughout this report and is presented in more detail in appendices A to I. A list of the Ministry of the Environment ambient air quality objectives for Ontario is presented in appendix J.

In 1978, the network was upgraded with the installation of a telemetry system to improve the accuracy and quality of data. It also allowed the Ministry to obtain real-time readings from any continuous monitor in the region. The design of the system was such that 5-minute average $SO_2$ concentrations, computed by the field data loggers, were telemetered to the Ministry's central data acquisition unit in Sudbury. The system was alarmed such that a single 5-minute average above a preset limit triggered a telephone message to the Ministry's Abatement staff in order to notify them of potential $SO_2$ fumigations. Abatement staff would then investigate, and if necessary notify the offending source for appropriate action to be taken. A hard copy of a selectable number of 5 minute averages was also provided in order to closely follow the progression of potential fumigations. The central data acquisition system computed and stored only the hourly averages on a cassette tape; the hourly data were edited and then transferred via hard copy printouts to the Ministry's Provincial database in Toronto.

The telemetry system was enhanced in 1985 by upgrading the field data loggers and the central data aquisition system. This provided increased data storage in the data loggers and greater communication capabilities between the central computer and the data loggers. This computer was equipped with a 15 megabyte hard disk for storage of data and operating programs, together with a number of communication ports. Inco Ltd. and Falconbridge Ltd. were provided access to the central computer through a communications port in order to obtain the sulphur dioxide data on a real-time basis for inclusion into their supplementary control systems (discussed in more detail later in this report). The system was also designed to electronically transmit data to the Ministry's Air Resources Branch computer in Toronto for inclusion into the Provincial air quality information system and for generating the hourly AQI values. Subsequent updates to this system have been made in recent years to increase the storage capacity and report generating capabilities.

The results of the routine air quality monitoring program conducted by the Ministry in the Sudbury area prior to 1978 have been published in previous reports (1,2,3,4,5).

# 4. GASEOUS POLLUTANTS

## 4.1 Sulphur Dioxide ($SO_2$)

Sulphur dioxide is one of the world's most common atmospheric contaminants. It is also one of the main contributors leading to the formation of acid rain. In Sudbury, there are two principal sulphur dioxide emitters: Inco Ltd. and Falconbridge Ltd. Inco is the largest single point source of $SO_2$ in North America; hence, the $SO_2$ monitoring network is an integral part of Sudbury's air management program. $SO_2$ emissions from Inco and Falconbridge from 1978 to 1988 are presented in table 2 and graphically in figure 3. Also included, is a bar graph depicting historical emissions from Inco and Falconbridge. This bar graph is presented in figure 3a and covers the period from 1967 to 1988. A much smaller $SO_2$ contribution in Sudbury is accounted for by fuel burning for domestic space heating. Sulphur dioxide is monitored by continuous analyzers and may be measured semi-quantitatively with passive samplers (sulphation plates). Details of the monitoring method used in the Sudbury network are presented in appendix A.

The Ontario air quality objectives for $SO_2$ based on known health effects and vegetation injury are:

0.25 ppm - 1-hour average
0.10 ppm - 24-hour average
0.02 ppm - annual average.

In 1978, the $SO_2$ network consisted of 17 stations as indicated by table 1 (locations are mapped on figure 1/1A). Since then, many changes to the network have taken place. Table 3 records the commissioning, decommissioning and/or relocation of the monitoring sites that have taken place between 1978 and 1988. The majority of these changes consisted of the decommissioning of the more distant stations from the smelters and the relocation of some of the monitoring stations closer to the City of Sudbury and to the smelters because of significant improvements in air quality outside the Sudbury basin due to decreasing emissions and greater dispersion of contaminants from Inco's tall stack at Copper Cliff.

Under Ministry control order requirements, Inco Ltd. has operated two mobile $SO_2$ monitoring units since 1978, whereas Falconbridge has operated three fixed stations since November 1984. The Ministry of the Environment performs routine audits on company-owned and operated analyzers to ensure satisfactory data quality.

By 1987, the sulphur dioxide network had decreased to 10 monitoring stations, 3 of these being a part of the Air Pollution Index (API) system.

In October of 1987, a new station (77218) was added to the Ministry's sulphur dioxide monitoring network. The station was located in the Copper Cliff townsite to monitor the impact of fugitive (low-level) emissions from Inco's Copper Cliff smelter.

The adequacy of the Ministry's $SO_2$ monitoring network in the Sudbury area is reviewed on a regular basis in light of changing circumstances and identified needs.

## Analysis of Data

As shown in table 3, a total of 24 Ministry $SO_2$ monitoring stations operated for some period of time in the Sudbury area from 1978 to 1988; 6 of these stations operated for the entire 11 year period. For the purpose of analysis and interpretation in this report, the 6 stations that monitored for the entire 11 years will be used when discussing trends and changes in Sudbury's air quality for $SO_2$. It would be difficult to assess the remaining 18 stations in the same manner because they operated for only part of the 11 years, ranging from 2 to 8 years.

$SO_2$ pollution roses for these 6 stations were generated for the period from 1978 to 1988 and are shown on the map in figure 27. In addition, pollution roses for the Science North and Copper Cliff stations were also included. A pollution rose for $SO_2$ is a crosstabulation of hourly averaged $SO_2$ concentrations with corresponding windspeed and wind direction data. The results in figure 27 generally show that higher average $SO_2$ concentrations were observed at the directions in line with Inco Ltd. and Falconbridge Ltd. operations.

The Copper Cliff station was found to have the highest average $SO_2$ concentrations in comparison to the other sites. Most of the $SO_2$ measured at this site results from fugitive (low-level) emissions from the converter aisle at the Inco Ltd. Copper Cliff operation.

### 4.1.1 Annual mean $SO_2$ Levels

The annual mean $SO_2$ levels for each station indicate that concentrations have remained relatively constant with a slight lowering at some stations (see table 4). Figures 4-4a to 9-9a display the annual means and trends of these 6 $SO_2$ monitoring sites: Skead (77012), Hanmer (77013), Garson (77065), Ash Street (77016), Coniston (77028) and New Sudbury (77075). Ash Street, Coniston and New Sudbury have shown the greatest decrease in the annual means as indicated by the decreasing trend lines. Of the 6 stations, Skead, Ash Street and New Sudbury recorded the highest annual means; however, these values were well below the yearly objective of 0.020 ppm. Of the total 24 monitoring sites, Happy Valley (77023) was the only station to marginally exceed the annual objective, recording a mean of 0.022 in 1979. The Happy Valley

(77023) monitoring station, which was located in a valley just south of the Falconbridge smelter, was removed in 1983 several years after Falconbridge Ltd. had purchased the properties from the residents.

In 1988, the Copper Cliff station (77218) recorded an annual arithmetic mean of 0.019 ppm $SO_2$, just slightly below the yearly Provincial objective. As stated previously, fugitive emissions were largely responsible for the high annual mean.

A correlation was attempted between Inco's $SO_2$ emissions in tonnes/year and the annual mean $SO_2$ levels for Ash Street from 1978 to 1988. The Ash Street station is situated 4 kilometers northeast of the Inco smelter and is in line with the southwest prevailing wind direction. The bar graph in figure 10 displays Inco's emissions and the corresponding annual $SO_2$ levels recorded at Ash Street. A regression analysis was also performed and is displayed in figure 10a. The correlation co-efficient (r= 0.4) statistically shows little significance between these two parameters. This analysis was applied to other sites and found to be typical. These results suggest that annual mean $SO_2$ levels in the Sudbury area are more strongly influenced by the frequency and intensity of short-term fumigations most often occurring from April to October than by gradual changes in annual emissions.

In summary, with the exception noted earlier at Happy Valley, the annual average concentrations of $SO_2$ in the Sudbury area were well in compliance with the Ministry's objective from 1978 to 1988.

Due to adverse atmospheric dispersion conditions occurring predominantly from April to October, "plume looping" results in short-term fumigations in the Sudbury area normally during the daytime. Also, fugitive emissions from the Copper Cliff smelter converter aisle often result in elevated short-term $SO_2$ concentrations close to the smelter complex.

The data for the frequency of exceedances of the Provincial 24-hour (0.10 ppm) and 1-hour (0.25 ppm) objectives and the 1-hour control order requirement (0.50 ppm) resulting from these fumigations for the period in question are presented in tables 5, 5a, and 5b. The maximum 24-hour and 1-hour concentrations recorded at each of these stations are presented in tables 6 and 6a.

### 4.1.2 24-Hour $SO_2$ Levels

The 24-hour objective was exceeded most often at Happy Valley (77023), recording 62 days above 0.10 ppm during a 5-year period. Of the 6 stations that operated for all 11 years, Skead recorded the most exceedances with 18 days above the objective. The frequency of exceedance for the 6 stations is found on table 7. This table is subdivided into two time periods, 1978 to 1983 and 1984 to 1988. Although the two time periods are not equal in number of years, they are however approximately equal in terms of the total tonnes of sulphur dioxide emitted by Inco and Falconbridge collectively, as shown in table 3. The data presented on table 7 indicate that there were substantially fewer exceedances of the 24-hour objective from 1984 to 1988, totalling 11% for all 6 stations. This is in comparison to 89% of the exceedances occurring from 1978 to 1983. For example, the most noticeable improvement was measured at Skead (77012). Only on 1 occasion from 1984 to 1988 did Skead record a value which exceeded the 24-hour objective. This is in comparison to 17 exceedances that occurred from 1978 to 1983.

The total number of 24-hour exceedances for the six stations is also presented in table 8 and are listed by year. The years 1976 and 1977 were included to better show the significant reductions that have taken place after 1978. These reductions are also displayed graphically in figures 11 and 11a which were generated from the data in table 8. The rural stations well removed from Inco and Falconbridge very seldom recorded 24-hour averages greater than 0.10 ppm of $SO_2$ and for this reason were removed and/or relocated to other areas which needed to be assessed.

In 1988, the 24-hour objective was exceeded most often at the Copper Cliff station which recorded 6 days over the objective of 0.10 ppm $SO_2$.

### 4.1.3 1-Hour $SO_2$ Levels

Happy Valley (77023) recorded the greatest frequency over the 1-hour objective with 668 hours from 1978 to 1982, 212 of these hours occurring in 1979 alone. Of the 6 stations that were fully operational for the 11 years, Skead (77012) and Coniston (77028) recorded the greatest number of 1-hour exceedances with 496 and 235, respectively. By referring to table 7, the data for the 1-hour objective show that the majority of exceedances for the 6 stations, with the exception of Ash Street, occurred from 1978 to 1983. From the total, approximately 63% of the exceedances occurred from 1978 to 1983 as compared to 37% from 1984 to 1988. The data for the 6 stations are also grouped another way and are presented in table 8. In this table the total number of exceedances of the 1-hour Provincial objective (0.25 ppm) for the 6 stations are listed for each year from 1976 to 1978. The data from tables 7 and 8 indicate that there has been a significant decrease in the number of hourly fumigations, especially in recent years, with 1988 recording the least number of exceedances. This improvement is also illustrated by the bar graph and trend in figures 12 and 12a, which were generated from the data in Table 8.

Of the 11 stations that were operating in 1988, the Copper Cliff station most often exceeded the 1-hour Provincial objective, recording 85 hours averaging over 0.25 ppm $SO_2$ for that year.

### 4.1.4 $SO_2$ Supplementary Control Program

With their existing smelting process, both Inco Ltd. and Falconbridge Ltd. cannot meet, at all times, the short-term hourly $SO_2$ objective (0.25) and the half-hour standard (0.30) in Regulation 308 of the Environmental Protection Act due to the short-term fumigations as discussed above. Consequently, since 1978 for Inco Ltd. and 1984 for Falconbridge Ltd., the Ministry has required through a control order, that both companies institute a "Supplementary Control Program" to reduce their $SO_2$ emissions, through production curtailments, during periods of poor atmospheric dispersion. A tentative ground-level concentration of 0.50 ppm for any 60-minute period was chosen as the control limit. All exceedances of this limit are reviewed and, if required, investigated by the Ministry to determine if the companies were diligent in the implementation of supplementary controls.

The implementation of the "Supplementary Control Program" proved to be successful in reducing short-term $SO_2$ episodes. As shown in table 8, the number of exceedances of the 1-hour control order requirement (0.50 ppm) has decreased significantly since 1978, the time when Inco Ltd. was required by the Ministry to implement these controls. The number of exceedances of the control limit in 1976 and 1977 were 95 and 90, respectively for the 6 stations. Since 1978, the number of episodes has decreased significantly, ranging from 33 to 4 times between 1978 to 1988. These improvements are also displayed graphically by the bar graph and trend line in figures 13 and 13a. Another factor responsible for the improvements witnessed since 1978 is a significant change in the smelting process at Falconbridge Ltd resulting in lower emissions.

The data above show that 1978 was a "transition year" leading to improvements in the number of short-term $SO_2$ fumigations. Although not as evident as the situation described above, further improvements are also observed to have taken place after 1984, when the Ministry required Falconbridge Ltd. to implement a supplementary control program. Table 8 shows that the number of $SO_2$ episodes decreased after 1984. With the exception of a low number of fumigations occurring in 1982 as a result of major shutdowns for both Inco Ltd. and Falconbridge Ltd. (see table 2), the period from 1985 to 1988 constitute the lowest number of $SO_2$ episodes on record.

Although not reflected in table 8, mention should be made of the Copper Cliff $SO_2$ station which exceeded the control order requirement of 0.50 ppm $SO_2$ a total of 29 times in 1988 as a result of roof-level fugitive smelter emissions. This is more than the combined exceedances of the other 10 stations operating in 1988.

The present control order on Inco Ltd. deals specifically with stack emissions only. Hence, Inco Ltd. has been requested to address the fugitive emissions problem and to propose an abatement program for controlling and reducing these emissions to acceptable levels.

In summary, the reduction of short-term $SO_2$ fumigations (1-hour and 24-hour) occurred mainly since 1978 and once again after 1984. These 2 "transition" years are a reflection of improvements from changes in the smelting process at Falconbridge Ltd. in 1978 and the implementation of the $SO_2$ supplementary control program for Inco Ltd. in 1978, and for Falconbridge Ltd. in 1984.

Also being addressed by the Ministry at the present time through separate regulations are the annual emissions of both Inco and Falconbridge as part of the Ministry's Countdown Acid Rain Program which was implemented in 1986. The purpose of this program is to lower $SO_2$ emissions at the four major corporate sources in Ontario through a series of staged reductions. An emissions cap of 265 kt/yr for Inco Ltd. and 100 kt/yr for Falconbridge Ltd. is the objective to be achieved by 1994 (9). As mentioned previously, decreases in annual emissions will not necessarily result in reduced $SO_2$ fumigations in the Sudbury area;, however, it will reduce acidic deposition of $SO_2$ as acid rain in certain parts of Eastern Canada and the Eastern United States.

## 4.2 Sulphation Rate

Sulphation rate is a semi-quantitative measurement of reactive sulphur compounds present in the air. The technique used to measure sulphation rate involves the use of small plastic plates coated with lead peroxide ($PbO_2$) which are exposed to the atmosphere for 30-day periods. The lead peroxide reacts with gaseous sulphur dioxide to form lead sulphate. The method, which is described in more detail in appendix B is normally used to detect the presence of sulphur dioxide; however, other reactive sulphur compounds such as hydrogen sulphide ($H_2S$) may also be converted to the sulphate form. It is an inexpensive method that can be used to "map out" locations of elevated $SO_2$ concentrations by deploying a number of these sampling devices. However, due to the inherent inaccuracies in the sulphation rate monitoring method, its use has decreased over the years.

The Provincial objective for sulphation rate is:

0.70 mg $SO_3$/100 $cm^2$/day - averaged over a 30-day period.

In Sudbury, sulphation rate was monitored at 11 locations from 1978 to 1980 as listed in table 1 and mapped in figure 2. The samplers were positioned throughout the city for the purpose of supplementing the data collected by the continuous $SO_2$ analyzers. In 1980, all of the sulphation rate monitoring sites were discontinued due to the adequacy of the historical data base and also due to the increased reliance on real-time measurements using continuous analyzers.

### Analysis of Data

The annual mean sulphation rates from 1978 to 1980 and the number of exceedances of the Provincial objective for each year are presented in table 9.

The highest annual mean sulphation rate was measured at the downtown Sudbury locations (Ash Street 77016 and Lisgar Street 77026) for each of the 3 years. The highest annual mean was recorded at Ash Street averaging 1.03 mg $SO_3/100\ cm^2$/day in 1980. Higher means at all 11 stations occurred in 1980, resulting from elevated levels in June and July for 6 of the 11 stations which were located north to west of Inco's operations, in line with the prevailing southwesterlies. The results for 1980 however, do not constitute a full year of data as indicated in table 9. Lower annual means in 1978 and 1979 correlate with decreased emissions from Inco resulting from labour strikes in both years as shown in table 2. In comparison to previous years, the annual sulphation rates at all 11 stations with the exception of Ash Street are comparable, fluctuating only slightly.

The greatest number of exceedances of the monthly objective was also measured at the two downtown locations, Ash Street and Lisgar Street, recording 12 and 8 exceedances respectively for the 3 years.

### 4.3 Oxides of Nitrogen (NOX)

Oxides of nitrogen (NOX) is taken to be the sum of nitric oxide (NO) and nitrogen dioxide ($NO_2$) concentrations in the atmosphere. Nitric oxide is a colourless, odourless gas while nitrogen dioxide is brown in colour and has a pungent odour. Both NO and $NO_2$ may be emitted from natural and man-made sources. NO and $NO_2$ are formed naturally by lightening and the action of soil bacteria; however it is the man-generated (anthropogenic) sources that are of greatest concern. The primary source is high temperature fuel combustion with transportation accounting for approximately 60% of anthropogenic emissions in Ontario. Secondary sources include power plants, incinerators and chemical processes.

Nitric oxide has no known adverse effects; however it oxidizes in the atmosphere to form $NO_2$ which can adversely affect vegetation, health, and visibility. $NO_2$ reacts with hydrocarbons and sunlight to form ozone. It may also combine with moisture in the atmosphere to form nitric acid ($HNO_3$), a contributor to acid deposition. Oxides of nitrogen are monitored with continuous analyzers, as explained in greater detail in appendix C.

There are no air quality objectives for NO, however, the Ontario objective for $NO_2$ based on health are:

0.20 ppm - 1-hour average
0.10 ppm - 24-hour average

In Sudbury, monitors for NOX (NO + $NO_2$) operated at Ash Street (77016) from 1978 to 1985 and at Science North (77203) from 1984 to 1988. A summary of these data is presented in table 10 and the annual $NO_2$ levels are displayed graphically in figure 14.

## Analysis of Data

### 4.3.1 Nitrogen dioxide ($NO_2$)

There is no annual objective for nitrogen dioxide; however, annual $NO_2$ levels decreased from 0.012 ppm at Ash Street (77016) in 1978 to approximately half this value from 1979 to 1985. Annual means recorded at Science North (77203) remained constant from 1984 to 1988 and were slightly higher than at Ash Street in 1984 and 1985, a period of time when both stations were operating simultaneously. This may be attributed to the fact that the Science North monitor is located close to a major roadway and is thereby affected more by automobile emissions. There were 3 values above the 1-hour objective of 0.20 ppm recorded at Ash Street in 1984. No values were recorded above the 1-hour objective at Science North from 1984 to 1987. The 24-hour objective for $NO_2$ of 0.10 ppm was not exceeded at either location from 1978 to 1988.

### 4.3.2 Nitric oxide (NO)

Annual mean levels for nitric oxide at Science North (77203) were higher on average for 1984 and 1985 as compared to Ash Street (77016). This is explained once again by the greater volume of traffic impacting the Science North monitor.

Nitric oxide levels varied at the Ash Street location from 1978 to 1985 with the lowest annual mean of 0.005 ppm recorded in 1983 and the highest value of 0.010 ppm recorded in 1985.

In summary, ambient concentrations of NO and $NO_2$ were low and well within the Provincial objectives from 1978 to 1988.

### 4.4 Total Reduced Sulphur (TRS)

Total reduced sulphur (TRS) is comprised of sulphur-containing gases which include hydrogen sulphide ($H_2S$) and methyl mercaptans. The odour threshold for TRS occurs at very low concentrations (approximately 5 ppb). At higher levels (approximately 100 ppb) TRS poses a problem to sensitive individuals who may experience nausea and headaches due to severe odours (6). At these levels TRS may also injure vegetation (7).

The Provincial objective for TRS based on odour is:

27 ppb - 1-hour average (expressed as hydrogen sulphide, a gas which is assumed to be the major component of TRS).

This objective was established primarily for emissions from pulp and paper mills using the Kraft pulping process.

There are no known significant sources of TRS in Sudbury. There are a number of Kraft mills in the Northeast region; however, these sources are far removed from the City of Sudbury. Emissions from E.B. Eddy Forest Products Ltd., which is situated approximately 70 kilometers west-south-west of Sudbury in the town of Espanola, have on occasion been detected at low concentrations by the TRS monitor located at the Science North complex. Another potential source of low levels of TRS are sewage treatment facilities, particularly during upset conditions (6).

TRS has been monitored by a continuous analyzer (refer to appendix D) at the Science North complex since 1984. A summary of the data for TRS is presented in table 11.

### Analysis of data

Annual levels were very low with the highest mean (0.7 ppb) recorded in 1985. These concentrations are generally low in comparison to other urban centres in the province.

There were no exceedances of the 1-hour and 24-hour Provincial objective of 27 ppb. The highest 1-hour level was 10 ppb in 1987 and the highest 24-hour average occurred in 1988 with a value of 9 ppb recorded. In both cases, winds were blowing from the southwest to west indicating E.B. Eddy as the probable source.

In summary, TRS levels are generally very low in the City of Sudbury.

## 4.5 Carbon Monoxide (CO)

Carbon monoxide is a colourless and odourless gas. Transportation (motor vehicles) is the primary source accounting for approximately 80% of man-made emissions. Secondary sources include fossil fuel combustion for building, heating and commercial/industrial operations. This pollutant is measured with a continuous analyzer as described in appendix E. Elevated levels of CO cause well known health effects.

The Ontario air quality objectives for CO based on health are:

30 ppm - 1-hour average
13 ppm - 8-hour average.

In Sudbury, this contaminant was monitored at two locations; Ash Street (77016) from 1978 to 1987 and at Science North (77203) from 1984 to 1988.

### Analysis of Data

A summary of CO levels is presented in table 12 and displayed graphically in figure 15. There is no Provincial objective for annual levels of carbon monoxide; however, annual concentrations in Sudbury are relatively low compared to other parts of the province. For example, the Ash Street (77016) station recorded the lowest annual mean in Ontario for 1988. The highest means at Ash Street (77016) occurred in 1978 and 1979 with values of 0.3 ppm and 0.2 ppm respectively, and then decreased to 0.1 ppm in 1980 where it has remained. Annual averages recorded at Science North (77203) were significantly higher ranging from 0.4 ppm to 0.7 ppm from 1984 to 1988. This is a reflection of the greater volume of traffic (automobile emissions) in the area of Science North.

The 1-hour Provincial objective of 30 ppm and the 8-hour objective of 13 ppm were not exceeded at either location from 1978 to 1988.

## 4.6 Ozone (O3)

Ozone is a colourless gas which occurs naturally in the upper atmosphere (stratosphere) and is important to all life because it provides a protective layer that prevents excessive amounts of harmful ultraviolet radiation from reaching the earth's surface. It should not be confused with ground-level ozone, which is a secondary pollutant in the surface layer (lower atmosphere), formed as a product of photochemical reactions involving oxides of nitrogen and reactive hydrocarbons in the presence of sunlight. The 1-hour Provincial objective for ground-level ozone (referred to as ozone here on) is 80 ppb. Above this objective, ozone may be injurious to sensitive species of vegetation. At elevated concentrations it may adversely affect human health. Its formation and transport are largely dependent on meteorological factors (sunlight and wind) and it can be transported great distances in the atmosphere.

Ozone is measured with continuous analyzers (refer to appendix F) and has been monitored at the Ash Street station (77016) since 1974 and at Science North since 1984. The data from 1978 to 1988 are presented in table 13 and are displayed graphically in figure 16. The Ash Street monitor operated only until June of 1988; therefore, there was insufficient data to report an annual mean for 1988.

## Analysis of data

Annual mean ozone levels ranged from 13 to 22 ppb at Ash Street and from 24 to 30 ppb at Science North. The bar graph in figure 16 indicates that annual concentrations have remained fairly uniform, fluctuating slightly about the mean of 17 ppb and 26 ppb respectively. Ozone levels were observed to be higher at Science North as compared to Ash Street. The higher levels measured at Science North are felt to be a function of location and are not believed to represent an overall increase of ozone levels in the Sudbury area in comparison to historical data collected at the Ash Street site.

As presented in table 13, ozone concentrations exceeded the 1-hour objective of 80 ppb on a number of occasions. At Ash Street, the 1-hour objective was exceeded 44 times in 1978 and 23 times in 1979. The following years, the number of values over this objective was considerably lower. At Science North, the objective was exceeded 45 times in 1985 and 91 times in 1988 which was regarded as a high ozone year across Ontario. The majority of the values exceeding the 1-hour objective of 80 ppb were recorded during the spring/summer months. This seasonal variation in ground-level ozone is typical and can be explained in two ways.

Firstly, it is believed that most of the ozone measured at these stations is a function of long-range transport from southern sources. Higher ozone levels will therefore occur during the warmer months characterized by prevailing southwesterly winds, as shown by the wind roses in figure 26. Secondly, meteorological conditions such as warmer temperatures, strong solar insolation in the summer and extended hours of daylight provide favourable conditions for the formation of ozone.

Ozone concentrations also follow daily trends. Frequency distributions of daily variations for values that exceeded the 1-hour objective at Science North and Ash Street from 1978 to 1988 are displayed in figures 17 and 17a. Levels are shown to peak around late afternoon/early evening, shortly after solar insolation and temperature collectively would be at a maximum. In addition, there were also a number of occasions when values over the objective were associated with nocturnal ozone exceedances. The Sudbury area appears to experience a high frequency of "nightime" ozone. In many of these cases, pollution episodes were long-lived and were carried over from the afternoon. This phenomenon occurs when a nocturnal temperature inversion does not form, providing ideal conditions for downward mixing of the ozone residing in the upper layers of the boundary layer, therefore keeping concentrations high. An example is provided in figure 18. This line graph was generated for a period of 2 days in July of 1988, which was the longest ozone episode on record from 1978 to 1988. Levels are shown to peak around late afternoon/early evening and remain relatively high through the course of the evening. The back trajectory analysis shown in figure 18a was generated for this particular episode. The trajectory line traces the 48-hour path of the ozone which is shown to originate primarily in the midwest and eastern areas of the United States.

Pollution roses for ozone, which is a crosstabulation of hourly averaged ozone levels with corresponding windspeed and wind

direction data, were generated for the Ash Street site from 1978 to 1988, and at the Science North site from 1984 to 1988. The results displayed in figure 28 show that higher average ozone concentrations were observed at both sites when winds were blowing from a southerly direction.

Since most of the elevated ozone levels measured in Ontario results from long-range transport, emissions of precursor contaminants (e.g., oxides of nitrogen and reactive hydrocarbons) will need to be reduced in the United States for Ontario to achieve compliance with its hourly objective of 80 ppb.

## 5. PARTICULATES

Airborne particulate matter can be generated by both natural and man-made sources. Examples of natural sources include particulate matter emitted from forest fires, volcanoes, ocean spray and wind-blown soil. Typical man-made sources in the Sudbury area include industrial processess such as mining, smelting and processing and construction. Most of the particulate emissions from the Sudbury smelting industry in the Sudbury Basin originate from the Inco 381 meter tall stack (8). The degree to which particulates become harmful to human health and vegetation depends on the particle size and its chemical composition. In Ontario, particulate matter is measured as dustfall, total suspended particulates (TSP) and soiling index (COH), all of which are measured by different techniques according to varying size ranges of the material.

### 5.1 Dustfall

Dustfall is defined as larger particulate matter that settles out of the atmosphere by gravity (dry deposition) and is generally around 100 microns (a micron is one-millionth of a meter) in diameter. It is collected by open-top containers (referred to as dustfall jars) that are exposed for 30-day periods. The collected material is then weighed and expressed as a deposition rate in grams/square meter/30 days (refer to appendix G). Dustfall jars are normally located in areas with sources of coarse particulate fallout. They are generally employed to monitor nuisance emissions and are rarely considered as having health-related effects.

The Ontario air quality objectives for dustfall are:

7.0 $g/m^2/30$ days - Monthly objective
4.6 $g/m^2/30$ days - Annual objective (arithmetic mean)

Dustfall was monitored at 16 locations in the Sudbury area from 1978 to 1988, generally near sources of particulate fallout. The Ash Street (77016) monitor was commissioned to determine long-term trends of particulate levels in the City of Sudbury. The dustfall network has decreased over the years due to significant improvements in the control of local area sources (e.g. revegetation and land reclamation efforts), and also due to optical microscopy results showing samples to consist of a high percentage of natural sources such as soil particles and road dust. There were only 2 dustfall sites operating in the City of Sudbury in 1988, both of which were commissioned in response to residents complaining of dust problems from the Fisher Dry Pac slag crushing and screening operations adjacent to the Inco Ltd. smelter. A series of meetings involving concerned citizens, company officials, the municipality and the Ministry of the Environment has prompted Fisher Dry Pac to set up a voluntary abatement program aimed at reducing nuisance dust emissions believed to emanate from their operations.

## Analysis of Data

Results of dustfall data collected in the Sudbury area from 1978 to 1988 are presented in table 14, and a bar graph displaying the annual levels for Ash Street (77016), a site which is representative of general particulate levels in the city, is presented in figure 19. Locations of the dustfall jars are shown on the map in figures 2 and 2a.

A dustfall jar was installed at Ash Street (77016) in 1978 to monitor particulate levels in an area close to the downtown core but removed from heavy traffic arteries. This dustfall jar provided an indication of the general particulate levels in the City from industrial sources, (e.g. Inco Smelter and tailings area), as well as from dust generated by urban activities. The yearly mean dustfall levels were variable with 1983 and 1985 slightly above the Provincial objective of 4.6 $g/m^2/30$ days averaged over a year. The highest measured annual average of 5.8 $g/m^2/30$ days was recorded in 1983 and the lowest was 1.1 $g/m^2/30$ days in 1987. In 1988, monitoring at this location was terminated and there was an insufficient number of monthly samples to calculate the annual mean.

The monthly objective of 7.0 $g/m^2/30$ days was exceeded at the Ash Street site on only 4 occasions during the same period.

Total dustfall was monitored in downtown Sudbury at Lisgar Street (77026) from 1978 to November 1980. Annual averages were below the Provincial objective of 4.6 $g/m^2/30$ days for the three years. The monthly objective of 7.0 $g/m^2/30$ days was exceeded once in 1978.

Total dustfall was monitored on Auger Street (77030) in New Sudbury from 1978 to March 1979. This jar was installed to determine the impact of the Rainbow Concrete ready mix plant on settleable particulate in the area. The yearly mean value for 1978 (the only full year of data) was 2.8 $g/m^2/30$ days which is well below the Provincial objective. The monthly objective was not exceeded at this location. Monitoring was discontinued when the company relocated its ready mix plant.

Several dustfall jars were installed in the west end of the City to determine the impact of the Inco Ltd. Copper Cliff complex and its associated tailings disposal area on settleable particulate in the area. In numerical order, these sites include Southview Drive (77039), Tuddenham Avenue (77040), Oliver Street (77043), Highway 17 West (77051), Glover Street (77078), Kelly Lake Road (77082), Southview Dr./Industrial Rd. East (77083) and Industrial Road West (77084).

Total dustfall levels were monitored at Southview Drive (77039) from 1978 to October 1984. Annual averages were below the Provincial objective of 4.6 $g/m^2/30$ days (arithmetic mean) except for 1983. Monthly values were generally low, with three values recorded in June, September and November of 1983 above the Provincial objective of 7.0 $g/m^2/30$ days. These high values can be attributed to road dust and residential construction in the area at that time, and possibly blowing tailings.

Total dustfall levels were monitored at Tuddenham Avenue (77040) from 1978 to 1980. Yearly mean dustfall was below the objective in 1978 and 1979; however, the annual objective of 4.6 $g/m^2/30$ days was exceeded in 1980 with a mean of 6.0 $g/m^2/30$ days. The monthly objective was exceeded in July of 1978 and again in August 1980.

Total dustfall levels were monitored at Glover Street (77078) near the Tuddenham Avenue site from April 1978 to May 1979. The mean dustfall was above the Provincial objective in 1978. Elevated monthly levels were observed in August and November of 1978.

Total dustfall levels were measured at Oliver Street (77043) in the townsite of Copper Cliff from 1978 to October 1987. Yearly mean values exceeded the Provincial objective in 1978, 1979, 1980, and 1983. With the exception of one elevated value in February 1983, the high monthly values occurred during the spring and summer months from April to August and are associated with industrial activity in the Copper Cliff area. The station had been operating at this location since 1973. Significant improvements since about 1986 prompted the removal of this station.

Dustfall levels were measured at Highway 17 West (77051) from 1978 to October 1984. The annual mean values exceeded the Provincial objective only in 1983. Exceedances of the monthly objective were observed in September 1978, in May and June 1979, in

November 1980, in March, April and November 1981 and in February 1983. The relatively high values that occurred in March, April and November are indicative of blowing tailings episodes related to freeze-drying conditions on the Inco Limited tailings.

Dustfall levels were monitored at Kelly Lake Road (77082) from 1978 to February 1979 also for the purpose of monitoring blowing tailings. The yearly mean dustfall level in 1978 (the only full year of data) was below the Provincial objective. There were no values above the monthly objective during the 14 months the data were collected.

Total dustfall samples were collected at two locations on Southview Dr./ Industrial Road East (77083) from 1978 to October 1984 and Industrial Road West (77084) from 1978 to March 1979. Yearly mean dustfall levels exceeded the Provincial objective in 1983 at Industrial Road East. The objective was not exceeded at Industrial Road West during 1978 (the only full year of data). The monthly objective was not exceeded at the Industrial Road West location during 1978 and 1979; however, it was exceeded at Industrial Road East in July 1979, 1980, 1983, and in February 1983 and March 1981. The majority of these exceedances were attributed to blowing tailings.

Total dustfall was collected on Penman Avenue (77049) in Garson from 1978 to December 1980 as part of a program to monitor blowing sand from the Inco Garson flux pit. The yearly mean dustfall level exceeded the annual objective in 1980, recording a mean of 8.6 $g/m^2/30$ days. This high mean results from four elevated monthly values collected in May, September, October and November.

Total dustfall was collected on Falconbridge Highway (77089) in Garson from 1978 to December 1980. This location was also part of the sampling program to monitor emissions from the Inco flux pit. Yearly mean dustfall levels were slightly below the annual objective. The monthly objective was not exceeded during the three years the station was in operation.

Monitoring at Penman avenue (77049) and at Falconbridge Highway (77089) was terminated due to the implementation of a revegetation program which was successful in reducing blowing sand.

Total dustfall was collected at Old Falconbridge Road (77200) from 1982 to October 1984 to monitor settleable particulate from the new location of the Rainbow Concrete ready mix plant. Yearly mean dustfall levels were well below the Provincial objective. Monthly dustfall levels were low with no values above the objective.

A dustfall monitor was installed at the Travers Street Campus of St. Charles College (77210) in May of 1986 as a result of complaints of blowing slag dust from the Fisher Dry Pac slag crushing and screening operations, as discussed previously. Relocation of the College and subsequent construction at the site necessitated the relocation of the jar across the street to the corner of Spruce and Travers Street (77211). Yearly mean dustfall levels were well below the Provincial objective. Monthly dustfall values were also low with no values above the Provincial objective. In addition to total dustfall, these samples were also analyzed by an optical microscopy method used to identify the particulate matter and determine the percentage of each substance identified in the sample. Although dustfall levels at Spruce/Travers Sts. (77211) were well within the Provincial objectives, the results of the optical microscopy indicated the presence of slag material originating from Fisher Dry Pac operations. The percentage of slag material in these samples, when detected, ranged from 5% up to 80%.

In summary, annual dustfall levels in and around the City of Sudbury were found to be quite variable and generally within Provincial objectives. The higher annual means in 1983 are believed to have resulted from a combination of two factors. First, elevated monthly levels in February at Ash St. (77016), Hwy. 17 W (77051), Southview Dr./Industrial Rd. E (77083) and at Oliver St. (77043) were attributed to blowing tailings during freeze dry conditions. Secondly, elevated dustfall levels during the summer months at Southview Dr./Industrial Rd. E (77083), Southview Dr. (77039) and at Oliver St. (77043) may be explained by dryer conditions. The precipitation records provided by the Sudbury airport Atmospheric Services Department were reviewed. In comparison to other years from 1978 to 1988, precipitation in 1983 was on average, normal. However, dryer conditions were observed in the months of June and July recording 38.4 and 41.4 mm of rainfall respectively. These values were well below the normal of approximately 83.0 mm of rainfall during these months, and may explain the high dustfall levels witnessed.

The monthly results were found to be very site specific and seasonally dependent with lower values during the winter period. The frequency of exceedance of the monthly objective was generally low; excessive levels were usually attributed to re-entrained soil and road dust and episodic blowing tailings from Inco's operations. As stated earlier, the dustfall network was cut back substantially as a result of successful abatement of controllable sources.

## 5.2 Total suspended particulates (TSP)

Suspended particulates consist of smaller particles than dustfall and range in size from 0.1 to 100 microns. They remain entrained in the atmosphere for longer periods of time and hence, may be transported great distances. Natural and man-made sources of this material include smoke, dust, ash, pollen and wind-blown soil. Suspected health effects are associated with particles that are less than 10 microns in size which are capable of penetrating deep into the lung. TSP is measured with a hi-vol sampler, a device which draws a measured volume of air through a filter medium. The filter is weighed before and after exposure and the difference in weight determines the amount of particulate matter collected. This weight is then converted to a concentration in air expressed in micrograms /cubic meter ($ug/m^3$). In Ontario, glass fibre filters are normally used. The routine Provincial sampling schedule is a 24-hour sample collected every 6th day. Appendix H describes this sampling method in greater detail.

The Ontario air quality objective for TSP is:

120 $ug/m^3$ - 24-hour average
60 $ug/m^3$ - Annual (1-year) geometric mean

Hi-vol sampling has been carried out on a routine basis at 4 different locations in the Regional Municipality of Sudbury from 1978 to 1988. The location of these monitors are shown on the map in figure 2 and 2a. The Ash Street (77016), Lisgar Street (77026) and Copper Cliff (77070) sites operated continuously from 1978 to 1988. The Falconbridge station (77076) was installed in 1976 and operated on a routine schedule from that time to 1984; the sampling program was reactivated late in 1985 in order to determine the potential impact of stockpiled material at the Falconbridge Ltd. smelter site and was terminated in June of 1986. A summary of total suspended particulate data is presented in table 15 and in figures 20 to 23.

### Analysis of Data

### 5.2.1 Ash Street (77016)

TSP monitoring at this site began in 1971. This location is considered to be representative of the City of Sudbury that is removed from heavy traffic corridors yet exposed to the industrialized area to the west of the city. Generally, TSP values were low. Yearly geometric means did not exceed the Provincial objective of 60 ug/$m^3$ for any of the years from 1978 to 1988; geometric mean values ranged from 25 in 1988 to 42 ug/$m^3$ in 1980. These means are low in comparison to other industrialized areas in the province. A decreasing trend is evident as shown by the bar graph in figure 20.

The Provincial 24-hour objective of 120 ug/$m^3$ was exceeded once in 1978, 1985 and 1987 and twice in 1979.

### 5.2.2 Lisgar Street (77026)

This station is located in the downtown Sudbury core near heavy traffic arteries and was established in 1972. Annual geometric means were below the Provincial objective and have decreased slightly from a maximum of 54 ug/$m^3$ in 1980 to means ranging between 30 and 40 ug/$m^3$ from 1982 to 1988. A decreasing trend from 1978 to 1988 is also evident for this site as shown by the bar graph in figure 21.

The number of values above the 24-hour objective varied from 4 in 1978, to 2 in 1982 and 1987 and to 1 in 1981 and 1983. These values are considered to be low for downtown core areas.

### 5.2.3 Copper Cliff (77070)

Suspended particulate levels have been monitored in Copper Cliff (77070) since 1976 to monitor the impact of particulate emissions from the Inco Limited Copper Cliff smelter.

Yearly mean TSP values were below the Provincial objective from 1978 to 1988. The highest annual mean TSP occurred in 1980 with a geometric mean of 55 ug/m$^3$. These values decreased significantly after 1985 with means ranging from 29 to 33 ug/m$^3$ from 1985 to 1988. These values are considered to be low for an industrialized area. The bar graph displayed in Figure 22 shows a decreasing trend for TSP mainly resulting from the low geometric means recorded from 1985 to 1988.

The number of values above the Provincial 24-hour objective varied from four in 1980 and 1984, to two in 1979, 1982 and 1987 and to one in 1978, 1983 and 1988.

### 5.2.4 Falconbridge (77076)

A hi-vol sampler operated at the Falconbridge Post Office from 1976 to 1985 to monitor the impact of suspended particulate emissions from the Falconbridge Limited operations in the Falconbridge townsite. Monitoring was temporarily suspended for most of 1984 and 1985 because of documented low TSP levels witnessed after 1980. The sampling program was re-activated late in 1985 for a short period at the request of the Ministry's abatement section to monitor the potential impact on the townsite of stockpiled material at the smelter site. The station was terminated in June of 1986 on the basis of acceptable TSP concentrations.

Annual means were below the Provincial objective from 1978 to 1985, as shown in table 15. The highest annual geometric mean of 56 ug/m$^3$ was recorded in 1980. TSP values decreased significantly after 1980 recording yearly means continually below 40 ug/m$^3$ (see figure 23). The geometric means for 1984 and 1985 have been included; however, the low number of samples collected do not represent a full year of data.

The number of samples above the 24-hour objective varied from 7 in 1980, to 4 in 1978 and 1979 and to 1 in 1981, 1982 and 1983. There were no readings above this objective in 1984 and 1985.

### 5.2.5 Total suspended particulate (data interpretation)

An overview of the trends in TSP levels at each of these 4 stations from 1978 to 1988 show a discernable decrease after 1980. A combination of factors appear to be responsible for the TSP reductions observed: firstly, decreases in particulate emissions from the Inco and Falconbridge smelting operations in conjunction with an overall decrease in $SO_2$ emissions; secondly, decreases in particulate emissions from the 194 meter stack as a result of additional pollution controls and the decommissioning of the two 45 meter stacks at the pelletizing plant located at the Inco. Ltd. nickel-iron refinery complex; thirdly, decreases in wind-blown soil and tailings due to successful revegetation efforts and programs throughout the Sudbury area.

A comparison of the annual means at Copper Cliff, Ash Street and Lisgar Street reveal that TSP levels were generally higher at Lisgar Street as compared to the other two sites. The primary sources impacting upon the Copper Cliff site include episodic wind blown tailings, and fugitive emissions from the smelter. Ash Street may also be impacted by fugitive emissions from the Copper Cliff smelter as well as from urban activities (ie. traffic, construction and space heating). The Lisgar Street station is impacted less from Inco's operations in comparison to the other two sites; the higher TSP levels at that site can be attributed to urban activities from the downtown core.

In an attempt to identify the source(s) of suspended particulate, hi-vol/wind correlation analyses were carried out for the Copper Cliff, Lisgar Street and Ash Street sites for 1988, and at the Falconbridge site for 1983 as shown in appendices K to N. This analysis correlates 24-hour TSP levels with corresponding hourly recorded wind data. The results are expressed as a correlation co-efficient which is indicated along the vertical axis of the graph. The higher the correlation co-efficient, the more significant the relationship between TSP and wind data.

At the Copper Cliff site, as shown in appendix K, the analysis showed positive correlations with the NE and ENE wind direction sectors, implicating fugitive emissions from the Inco Ltd. Copper Cliff smelter. Positive correlations were also observed from the SE to the SW sectors. The only other point sources of significance lie to the SSW and SW, namely the Inco copper and nickel refineries and the sulphur products plant. Therefore general urban activity is believed to be the source of airborne particulate for the SE, SSE, and S sectors.

At the Ash Street site, as shown in appendix L, the analysis showed that positive correlations were obtained for the NNE, NE, ENE, SE, SSE, and S sectors, with general urban activity as the likely source of particulate. Positive correlations at the SW and WSW sectors implicate the Inco smelter as the predominant source.

As shown in appendix M, the analysis for the Lisgar St. site showed positive correlations from various sectors not associated with the smelting operation. The levels of suspended particulate matter at this site result mostly from general urban activity. The strong correlation for the SW component cannot be explained at this time.

At the Falconbridge site, this analysis was carried out for 1983, the last full year of operation before being discontinued in early 1984. The analysis in appendix N showed that most of the suspended particulate measured were from sources to the SW and SSW directions, resulting mostly from general urban activity in the Town of Falconbridge.

In summary, TSP levels in the City of Sudbury are low and well within the annual Provincial objective. Episodic events, such as blowing tailings during the spring and fall, adverse dispersion conditions for smelter emissions and other sources (ie. traffic, construction, and space heating) result in a small number of excursions of the daily objective.

### 5.2.6 TSP Metal analysis summary

Hi-vol filters collected in the Sudbury area from 1978 to 1988 were analyzed for trace metal content in addition to total suspended particulate loadings. The deposition of trace metals from local sources (ie. Inco and Falconbridge) is significant. Up to 70-80% of copper and nickel smelter emissions are deposited within an area of 40 kilometers of the City (8).

A portion of each filter was analyzed for metal content by atomic absorption, and the mass concentration expressed in $ug/m^3$ for the entire filter. Filters were analyzed for the following metals: iron (Fe), lead (Pb), nickel (Ni), copper (Cu), chromium (Cr), cadmium (Cd), manganese (Mn), zinc (Zn) and vanadium (V). Metal analysis for Cu, Ni and Fe which are the metals emitted in the highest quantity from area smelters were continuously carried out on filters from each of the 4 stations from 1978 to 1988. The other metals listed have shown only trace amounts over the years and were not analyzed for the entire period. The summary of data (annual levels and maximum 24-hour concentration) for metal analysis for Ni, Cu and Fe in TSP are presented in tables 16 and 17. Lead (Pb) has also been included in the next section due to the health-related concerns associated with this metal. The 24-hour objectives and limiting effects for these metals are as follows:

| Metal | Limiting Effect | Ambient Air Quality Objective |
|---|---|---|
| Iron (Fe) | Soiling | 25 ug/m$^3$ (as $Fe_2O_3$) |
| Lead (Pb) | Health | 5 ug/m$^3$ |
| Nickel (Ni) | Vegetation | 2 ug/m$^3$ |
| Copper (Cu) | Health | 50 ug/m$^3$ |

### 5.2.6.1 Iron (Fe)

Iron (Fe) levels exceeded the Provincial 24-hour objective of 25 micrograms/m$^3$ (expressed as $Fe_2O_3$) on only 3 occasions in the Sudbury area between 1978 and 1988. In 1987, this objective was exceeded once at Ash Street (77016) with a value of 46.2 ug/m$^3$, and once at Lisgar Street (77026) recording a value of 42.3 ug/m$^3$. In 1979, the 24-hour objective was marginally exceeded at the Copper Cliff (77070) site recording 28.2 ug/m$^3$. There were no exceedances of this objective at Falconbridge (77076).

Yearly geometric means indicate that iron levels were on average higher at Copper Cliff compared to the other sites and that levels have remained relatively constant and low at all 4 locations from 1978 to 1988.

#### 5.2.6.2 Nickel (Ni)

Nickel levels were well within the Provincial 24-hour objective of 2 ug/m$^3$ at all locations with the exception of Copper Cliff (77070). At this site, the 24-hour objective was exceeded on 2 occasions each in 1980, 1986, and 1988; the maximum levels recorded were 4.4, 2.3, and 6.1 ug/m$^3$ respectively.

Yearly geometric means at Copper Cliff (77070) were much higher compared to the other sites as shown in table 16. The means for that site are displayed graphically in figure 24. The elevated nickel levels at Copper Cliff are a reflection of low-level emissions from Inco's Copper Cliff smelter operations.

The lowest levels at Copper Cliff occurred in 1978 and 1982 which corresponds with reduced emissions from Inco's operations due to labour strikes. Reduced levels were also observed at Ash Street (77016) and Lisgar Street (77026) during these years. Nickel concentrations at all stations have remained fairly constant since 1985.

The annual mean nickel levels at Falconbridge (77076) are observed to have decreased appreciably after 1980, as shown in table 16.

In an attempt to identify the source(s) of nickel (Ni) in suspended particulate, hi-vol/wind correlation analyses were performed for Ni in TSP at the Copper Cliff, Ash Street and Lisgar St. stations for 1988 and at the Falconbridge site for 1983.

The most significant (positive) correlation was observed at the Copper Cliff station (see appendix O) at the ENE direction, implicating the Inco Ltd. Copper Cliff operation as the probable source. A secondary source was observed at the ESE direction, implicating the Inco nickel refinery.

At the Ash Street site, impact from Inco Ltd. is evident from the SW and WSW sectors (see appendix P), while at the Lisgar St. site (see appendix Q), there appears to be little significance to the levels of Ni in TSP with the directions in line with Inco's operation. In these particular cases, it is difficult to determine the source(s) of Ni in suspended particulate because a substantial number of the higher levels were observed when wind conditions were calm.

At the Falconbridge site, as shown in appendix R, the analysis reveals that Falconbridge Ltd., located to the east of the hi-vol station, is the predominant source of Ni in suspended particulate.

#### 5.2.6.3 Copper (Cu)

Copper levels in the Sudbury area were well within the Provincial objective of 50 ug/m$^3$. The highest levels were again observed at Copper Cliff (77070) reaching a maximum of 10.3 ug/m$^3$ for a single sample. Again, low-level emissions from Inco's Copper Cliff operations have the greatest impact at this site.

Annual levels are observed to be higher at Copper Cliff (77070) in comparison to the other sites. The annual levels for Copper Cliff are displayed graphically in figure 25. As was the case with nickel concentrations, copper levels were also lower at Copper Cliff (77070), Ash Street (77016) and Lisgar Street (77026) during the labour strike years at Inco, with the exception of Lisgar Street in 1982. Overall, there appears to be a decreasing trend of annual copper levels in the latter half of this period for these 3 stations, as seen in table 16.

Consideration must be taken when interpreting copper values collected using hi-vol samplers since some recent studies have identified a potential contamination problem from the erosion of the commutator on the hi-vol motors. Precautions are being taken now to vent the exhaust of the motor away from the sampler.

#### 5.2.6.4 Lead

Lead levels at all 4 sampling locations from 1978 to 1988 were low with no values above the Provincial objective of 5 ug/m$^3$. The highest maximum 24-hour value of 2.3 ug/m$^3$ was recorded at Lisgar Street site in 1978.

Annual geometric mean levels at Lisgar Street were generally higher compared to the other locations in the Sudbury area. Leaded gasoline and heavier traffic at that site are believed to explain these results. Lead levels should continue to decrease with the phasing out of leaded gasoline. This, coupled with the fact that Pb levels in Sudbury are much lower than in other urban centres of Ontario indicate that the levels of airborne Pb are quite acceptable in Sudbury.

### 5.3 Soiling Index (Co-efficient of Haze)

Soiling index (COH) is a measure of the soiling or darkening properties of very small airborne particles (less than 5-10 microns). It is also considered to be an indicator of suspended particulate concentrations. Soiling index is measured by a continuous (hourly) sampling device which is telemetered to the Ministry's Sudbury office; the data are then sent to a central computer facility in Toronto. A paper tape moves through this continuous sampling unit with a known volume of air drawn through the filter paper every hour. The light transmittance of the clean section of the tape before exposure is recorded. After exposure the reduction of the light transmitted through the same portion of the tape is also recorded and the difference is expressed as coefficient of haze (COH) per 1,000 linear feet of air sampled. Appendix I provides more detail into the operation of this sampling unit and the determination of COH. The same sources apply for COH as mentioned for all suspended particulate sources. The health effects for COH are also the same due to inhalation of the smaller particles (less than 10 microns).

The Ontario air quality objectives listed below are based on soiling and visibility effects.

1.0 COH units / 1,000 lin. ft. of air sampled - 24-hour average
0.5 COH units / 1,000 lin. ft. of air sampled - Annual average

Coefficient of haze samplers operated at Ash Street (77016), Coniston (77028) and New Sudbury (77075) from 1978 to 1988; at Lisgar Street (77026) from 1978 to 1980 and at Science North (77203) from 1984 to 1988.

## Analysis of Data

As stated earlier, the levels of suspended particulate determined from hi-vol monitoring in the Sudbury area were observed to be low. The co-efficient of haze data listed in table 18 confirm this. At no time from 1978 to 1988 did the soiling index exceed the annual objective at any of the 5 stations. The highest annual means occurred at Science North from 1984 to 1988, the highest in 1984 with a mean of 0.31 COH unit. The annual means recorded at Ash Street, Lisgar Street, Coniston and New Sudbury are among the lowest in the province and have changed very little, fluctuating slightly about a mean ranging from 0.19 to 0.12 COH units.

The 24-hour objective of 1.0 COH unit was not exceeded at Ash Street (77016) or Lisgar Street (77026). At Coniston (77028) this objective was marginally exceeded only once with a reading of 1.2 COH units in 1984. New Sudbury (77075) also marginally exceeded this objective in 1983 recording 1.2 COH units. Science North (77203) exceeded the 24-hour objective on 4 separate occasions: once each in 1984 and 1985, recording averages of 1.3 and 1.2 COH units respectively, and twice in 1987 with a maximum of 1.4 COH units.

## 6. METEOROLOGICAL DATA

Wind direction, wind speed and temperature are three important meteorological parameters which directly influence the transport and dispersion of pollutants in the atmosphere. The Ontario Ministry of the Environment collects these data at two sites in the Sudbury area, one located in the downtown core at the CKNC tower (77025) on Frood Road in Sudbury and the other in Hanmer (77013).

## 7. AIR POLLUTION INDEX

The Air Pollution Index (API) system has been in operation in Sudbury since January 1971. This warning system also operates at 10 sites in other major cities in Ontario with the purpose of alerting the public to elevated air pollution levels. It also plays an important role as a regulatory tool for curtailment of industrial emissions during air pollution episodes. The API is a dimensionless number computed each hour which is derived from 24-hour running average concentrations of sulphur dioxide ($SO_2$) and soiling index (COH). The combination of these pollutants at elevated levels may adversely affect human health. Hourly concentrations of $SO_2$ and COH are telemetered to the Ministry's central computer facility in Toronto which calculates the index hourly. The index equations are different for each city in Ontario. In Sudbury, the index is computed based on the following equation:

$$API = 4.98\ (5.30\ COH + 122.6\ SO_2)^{.65}$$

Where: COH is the 24-hour running average soiling index concentration expressed in coefficient of haze units.

$SO_2$ is the 24-hour running average sulphur dioxide concentration in parts per million (ppm).

If the API reaches a value of 32 and weather forecasts indicate that poor dispersion conditions will continue for at least

6 hours, an air pollution advisory is issued.

If the API reaches 50 (first alert level), with a forecast of adverse weather conditions for at least 6 hours, major sources will be ordered to curtail operations.

Further curtailment may be ordered if the API reaches 75 (second alert level). If the API reaches 100 (air pollution episode threshold level), the Ministry can order all sources not essential to public health or safety to cease operation until the weather conditions change producing good dispersion and a lowering of Air Pollution Index levels.

Three API stations operated in the Sudbury area from 1978 to 1988: Ash Street (77016), Coniston (77028) and New Sudbury (77075). Science North became the fourth API station when it was commissioned in June of 1988 as part of the new Air Quality Index (AQI) system.

## Analysis of Data

A summary of the API for these stations is presented in table 19, which lists the maximum index reached yearly, the number of hours greater than 32, the number of hours greater than 50 and the annual means for each of the 4 stations. Also listed at the bottom of the table are the dates and duration for each exceedance.

The API advisory level of 32 was exceeded once at Ash Street (77016) in 1983, reaching a maximum index of 39. There were no other elevated levels at this station from 1978 to 1988. The advisory level was exceeded at Coniston (77028) on four occasions; 3 times in 1978 reaching a maximum index of 34, and once in 1982 reaching a maximum index value of 39. New Sudbury (77075) exceeded the advisory level on two separate occasions from 1978 to 1988. In 1978, a maximum index of 42 was recorded, and in 1983 the API reached a maximum index value of 63, which is the highest on record since 1972. There have been no elevated API levels recorded at Science North (77203) since it was commissioned in June of 1988.

All of the API episodes have occurred in January and February and were caused by elevated $SO_2$ concentrations. The majority of the $SO_2$ fumigations in the Sudbury area usually occur in the warmer months; however, meteorological conditions usually favour more rapid dispersion of contaminants in the warmer months and fumigations are short-lived. In comparison, the colder winter months are characterized by stronger and longer lasting temperature inversions, conditions which may be unfavourable in terms of pollutant dispersion. The API episodes described above resulted from either stagnant or poor dispersion conditions during the night which caused a build-up of $SO_2$ ground-level concentrations for a number of hours.

As shown in table 19, there were no API values above 32 from 1984 to 1988. This reduction is a reflection of the successful implementation of Ministry-imposed $SO_2$ emissions curtailment programs incorporating real-time telemetry of $SO_2$ data.

## 8. AIR QUALITY INDEX

In May of 1988, the Ministry of the Environment implemented a new system to better inform the public on the quality of Ontario's air, the Air Quality Index (AQI). This system operates at 33 locations in 26 cities across the province. In Sudbury, the AQI station is located at Science North (77203). The system provides hourly information for the 6 most common urban air contaminants:

total reduced sulphur (TRS)
carbon monoxide (CO)
nitrogen dioxide ($NO_2$)
ozone ($O_3$)
sulphur dioxide ($SO_2$)
suspended particulate (COH)

The Air Pollution Index (API) continues to serve as a regulatory tool and in addition, is incorporated as a sub-index of the new AQI system.

The Ontario AQI was adopted from the Canadian Air Quality Index and the U.S. EPA Pollutant Standards Index. The descriptive categories and numerical values, however, are related to Canadian standards (Federal and Provincial/Ontario) which differ from that of the United States for each of the contaminants. A sub-index ranging from zero upwards is related to the hourly concentration of each of the contaminants. As the index increases, the air quality worsens. The sub-index is calculated for each contaminant based on its effect and the highest sub-index at any time becomes the AQI.

The AQI values are divided into 5 descriptive categories and reflect possible effects on health, vegetation, property, and aesthetic values:

| | |
|---|---|
| 0 - 15 | very good |
| 16 - 31 | good |
| 32 - 49 | moderate |
| 50 - 99 | poor |
| 100+ | very poor |

Table 20 displays a chart listing the air quality index contaminants and their impacts for each of the 5 descriptive categories.

## Analysis of Data

A summary of the 1988 data, showing the frequency distribution for the hourly index and the contaminant responsible for values greater than or equal to 32, is presented in table 21 for the Science North site. In summary, the very good to good air quality levels at Science North (77203) prevailed 98% of the time. This is slightly better than the Ontario average (96%) for all of the AQI stations. The remaining 2% fall into the moderate (32 to 49) and poor (50 to 99) range. There was no occurrence of very poor (100+) air quality. Also evident from the table, ozone is by far the most frequent cause of high index values (greater than or equal to 32) at Science North. Of the total 99 hours listed in the moderate and poor range, ozone was responsible for 82 of the 99 hours (approximately 83%). All of the 82 ozone hours were recorded in the summer months of June, July, and August. This situation correlates with most AQI sites in Ontario where ozone was the main cause of elevated AQI values in 1988 which in comparison to other years is considered to be a "high" ozone year.

The other contaminant responsible for the remaining 17 hours was sulphur dioxide (appoximately 17%). A further breakdown of the categories revealed that of the 12 hours listed as poor (50 - 99), $SO_2$ was the contaminant responsible.

# 9. CONCLUSIONS

During the 11-year period (1978-1988) covered in this report, the air quality in the Sudbury area, specifically for short-term $SO_2$ fumigations, has improved especially in the last half of this period. This improvement reflects the decrease in the frequency and intensity of short-term $SO_2$ fumigations resulting from Ministry -imposed "Supplementary Control Programs" on the area smelters. However, the control order limit for $SO_2$ of 0.50 ppm for 1-hour continues to be exceeded from time to time, such that improvements are required in the forecasting of periods with poor atmospheric dispersion conditions for timely curtailments of $SO_2$ emissions from area smelters.

Ambient levels of other routinely monitored gaseous contaminants such as carbon monoxide, oxides of nitrogen and total reduced sulphur were low and well within Provincial objectives. Ground-level ozone concentrations exceeded the Provincial hourly objective during the summer months on a number of occasions. Pollution roses and air mass trajectory analyses indicate that most of the ozone is imported into the Sudbury area from distant sources to the south, especially from the United States.

Particulate levels, historically within acceptable levels in the Sudbury area, were observed to decrease somewhat after 1980. This is attributed to decreases in particulate emissions from smelting operations, and to successful revegetation efforts which have reduced wind blown soil and mine tailings as sources of dust. Concentrations of copper, nickel, iron and lead in suspended particulate were usually well within acceptable levels, with the exception of nickel concentrations which on occasion were elevated at the Copper Cliff monitor.

From 1978 to 1983, the Air Pollution Index system recorded a small number of exceedances of the advisory level of 32. From 1984 to 1988, the advisory level was not exceeded.

The Air Quality Index system, established in June 1988, revealed very good to good air quality in Sudbury 98% of the time for 1988. The remaining 2% of the time showed moderate (88%) to sometimes poor (12%) air quality, with ozone (83%) and $SO_2$ (17%) as the problem contaminants.

## 10. ACKNOWLEDGEMENTS

The authors wish to express their gratitude and appreciation to Mr. W. Tremblay and his staff (Mr. D. Neve, W. Trayling, N. Salonikidis) for the successful operation and maintenance of the air quality monitoring network in the Sudbury area; to Mr. P. Kiely and Mr. P. Schaffer of the Air Resources Branch for their assistance with data retrievals from AQUIS; to Mr. D. Bazinet and Mr. R. Harrison for data compilation and tabulation and to Mrs. P. Strong for word processing support.

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# FIGURES

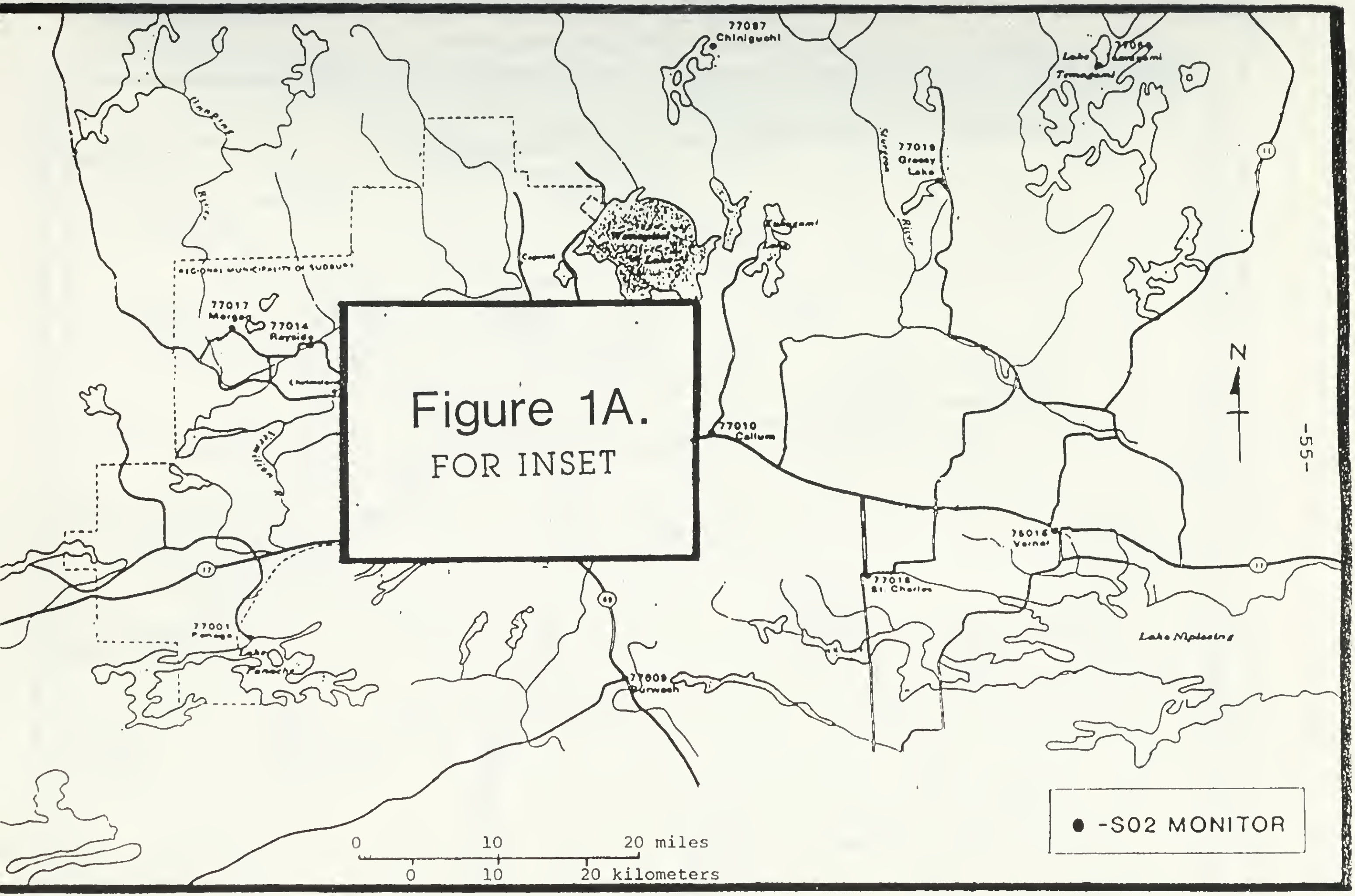


Figure 1. Locations of sulphur dioxide monitoring stations in the Sudbury area from 1978 to 1988

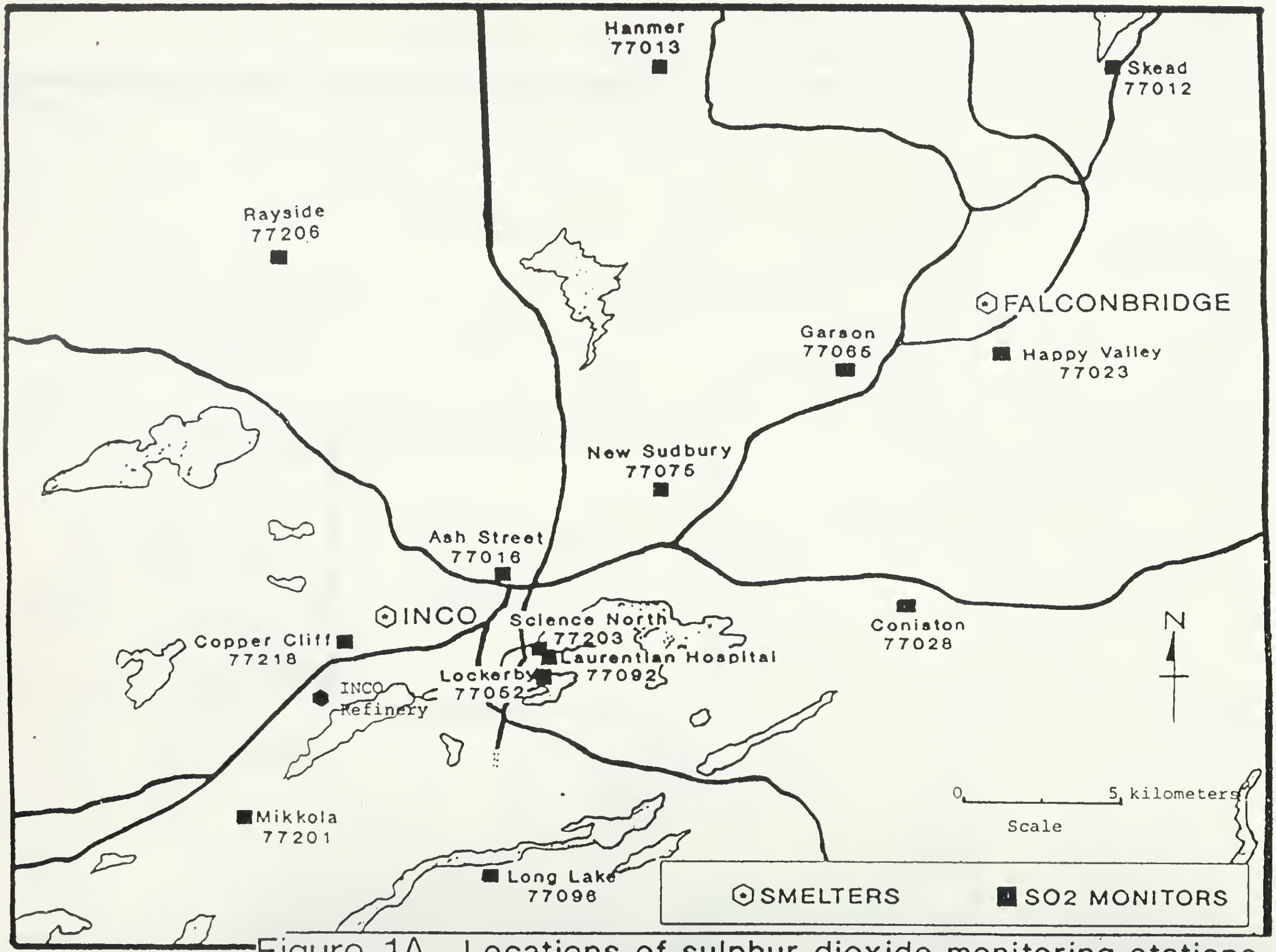
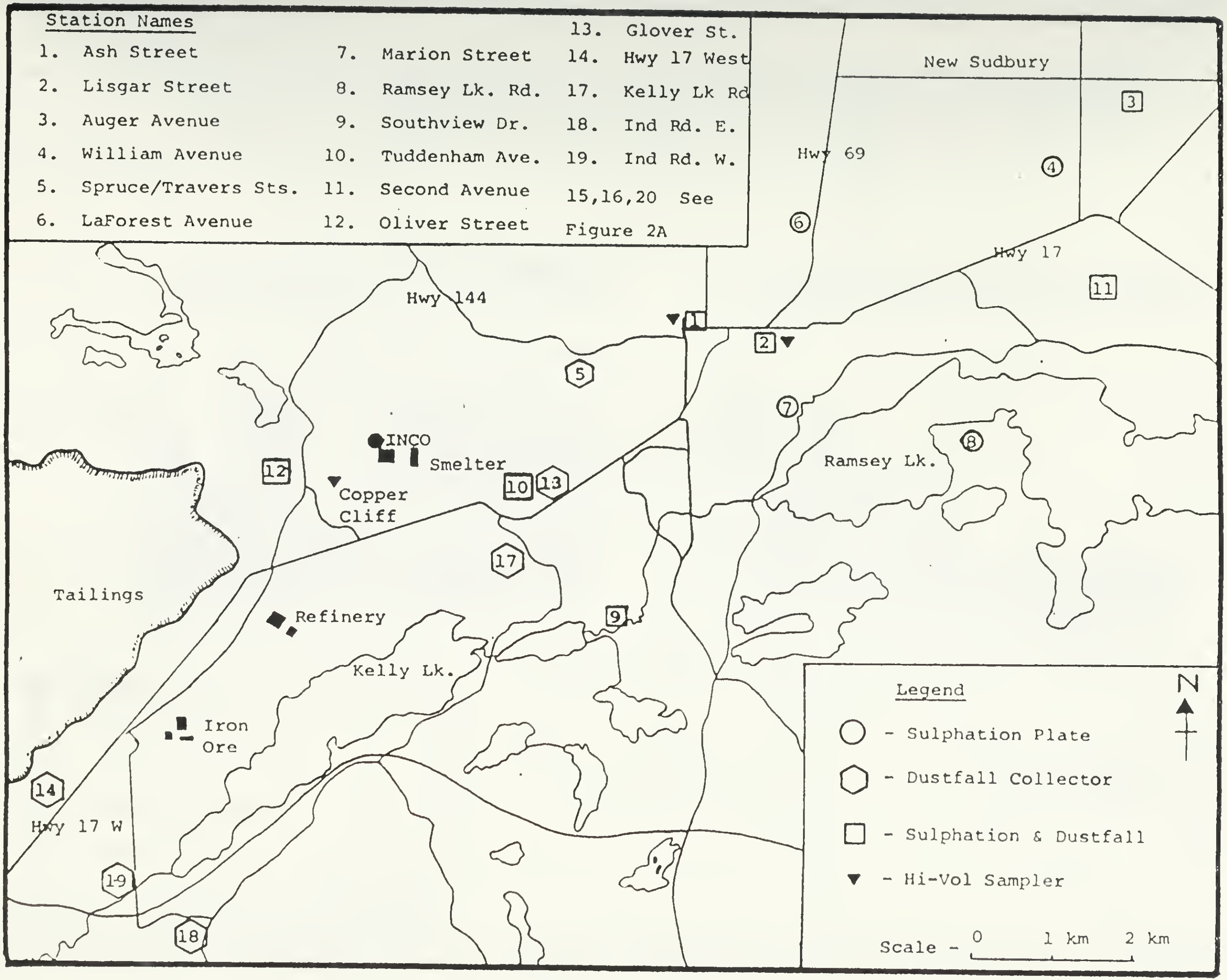


Figure 1A. Locations of sulphur dioxide monitoring stations in the Sudbury area from 1978 to 1988



Station Names

| | | | | | |
|---|---|---|---|---|---|
| | | | | 13. | Glover St. |
| 1. | Ash Street | 7. | Marion Street | 14. | Hwy 17 West |
| 2. | Lisgar Street | 8. | Ramsey Lk. Rd. | 17. | Kelly Lk Rd |
| 3. | Auger Avenue | 9. | Southview Dr. | 18. | Ind Rd. E. |
| 4. | William Avenue | 10. | Tuddenham Ave. | 19. | Ind Rd. W. |
| 5. | Spruce/Travers Sts. | 11. | Second Avenue | 15,16,20 | See |
| 6. | LaForest Avenue | 12. | Oliver Street | | Figure 2A |

Legend
- ○ - Sulphation Plate
- ⬡ - Dustfall Collector
- ☐ - Sulphation & Dustfall
- ▼ - Hi-Vol Sampler

FIGURE 2. LOCATIONS OF HI-VOL, DUSTFALL, AND SULPHATION RATE MONITORING FROM 1978 to 1988

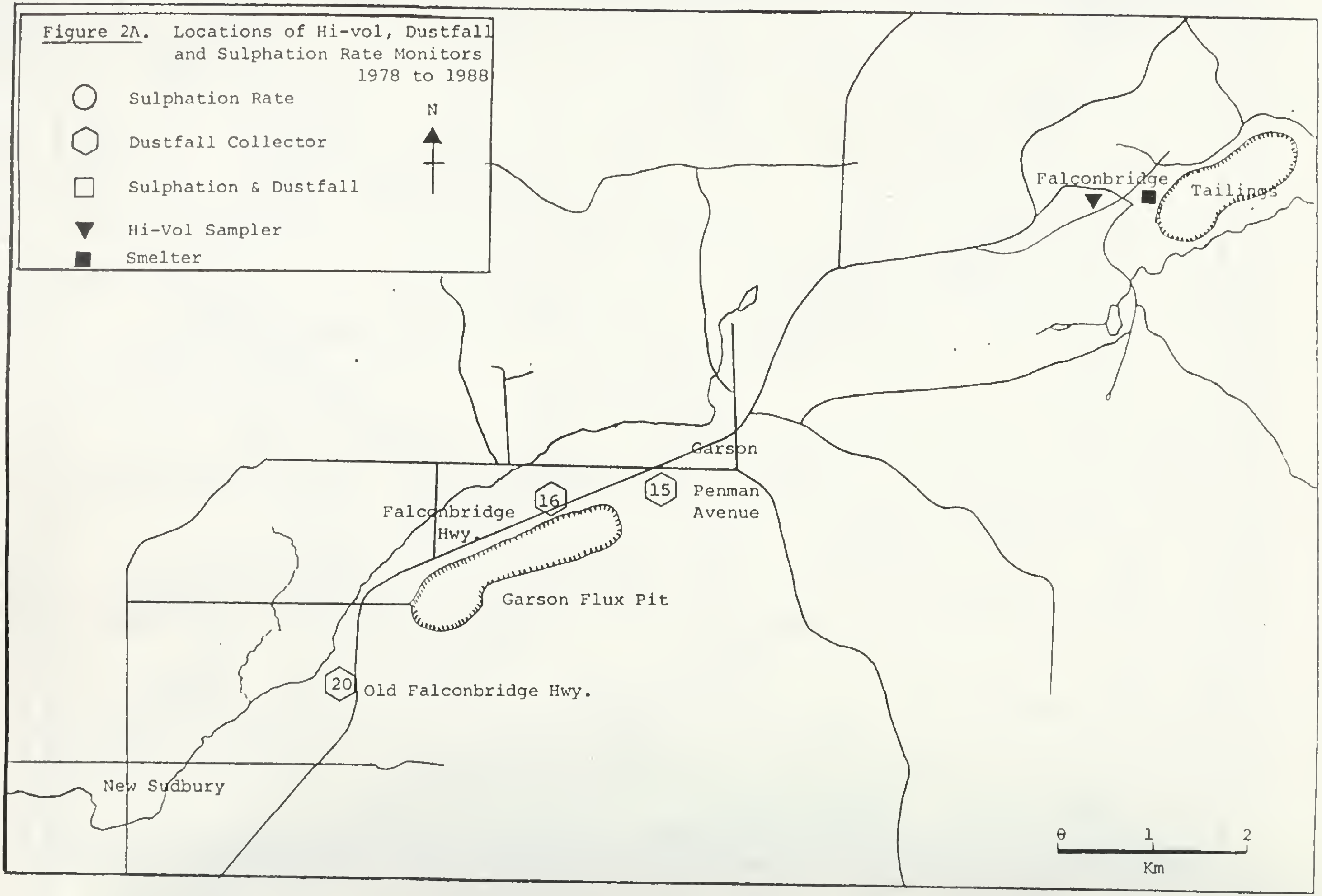


Figure 2A. Locations of Hi-vol, Dustfall and Sulphation Rate Monitors 1978 to 1988

SO2 EMISSIONS FROM INCO AND FALCONBRIDGE LIMITED IN SUDBURY FROM 1978 TO 1988

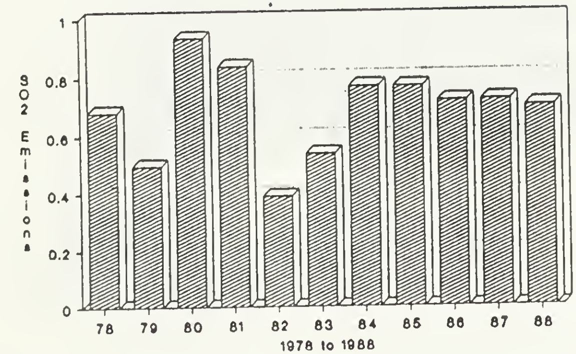


FIGURE 3

SO2 EMISSIONS FROM INCO AND FALCONBRIDGE LIMITED IN SUDBURY FROM 1967 TO 1988

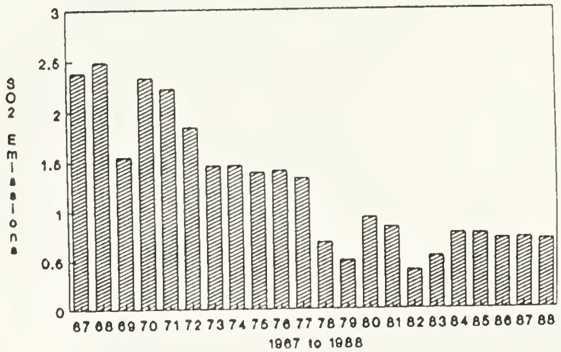
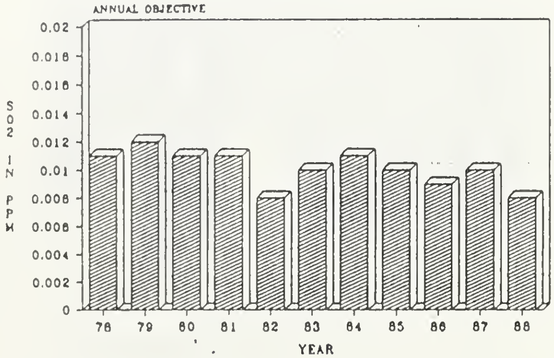


FIGURE 3A

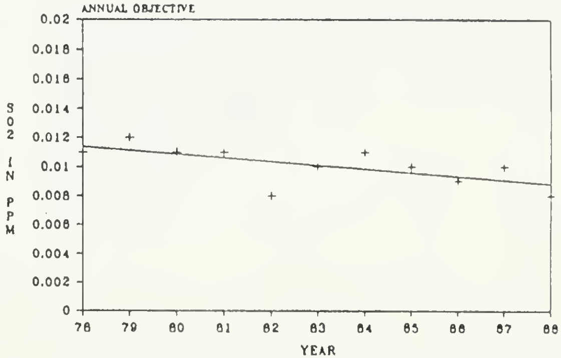
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT SKEAD #77012 FROM 1978-1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 4

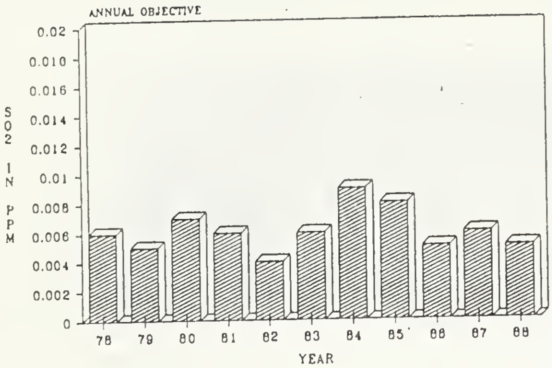
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT SKEAD #77012 FROM 1978-1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 4A

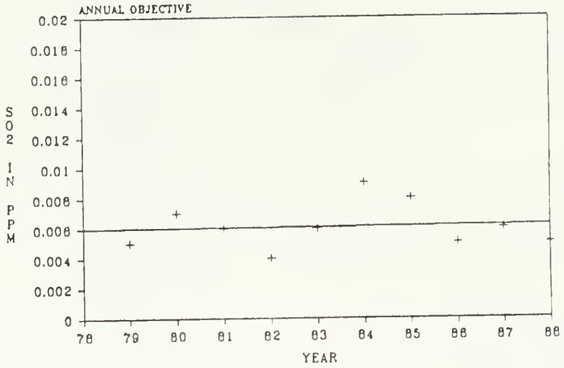
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT HANMER #77013 FROM 1978-1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 5

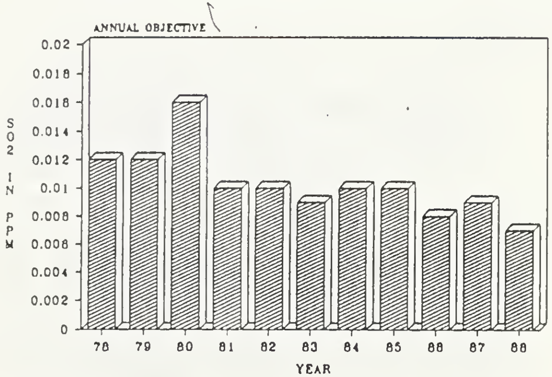
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT HANMER #77013 FROM 1978-1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 5A

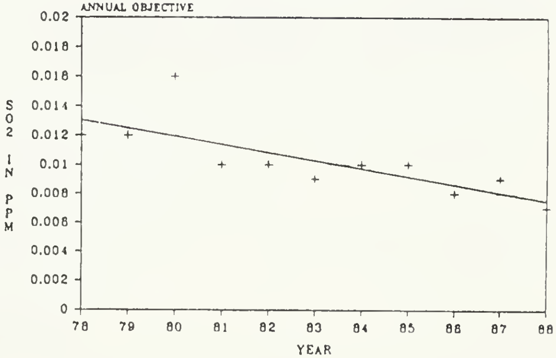
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT ASH ST. #77016 FROM 1978-1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 6

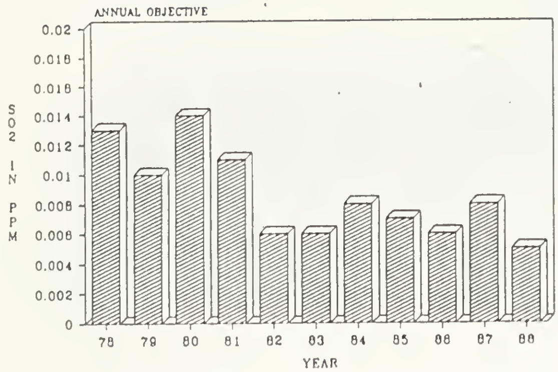
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT ASH ST. #77016 FROM 1978-1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 6A

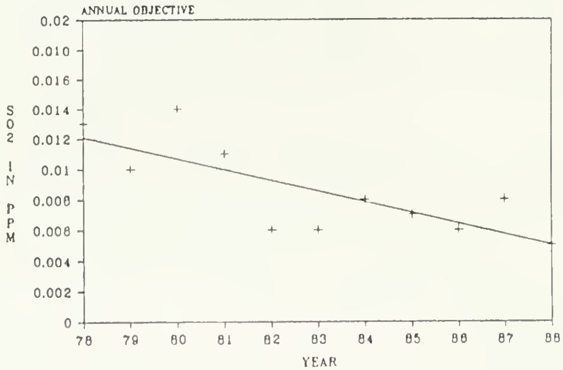
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT CONISTON #77028 FROM 1978-88



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 7

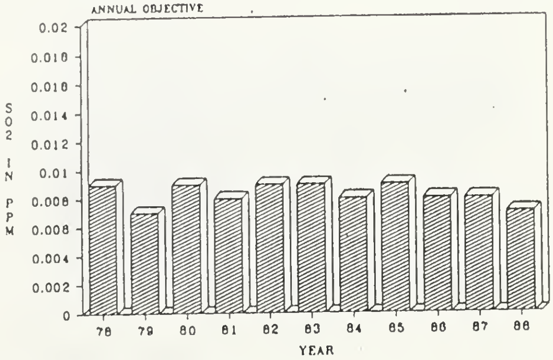
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT CONISTON #77028 FROM 1978-88



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 7A

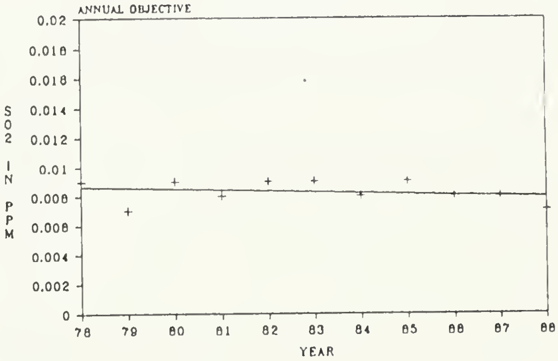
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT GARSON #77065 FROM 1978-1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 8

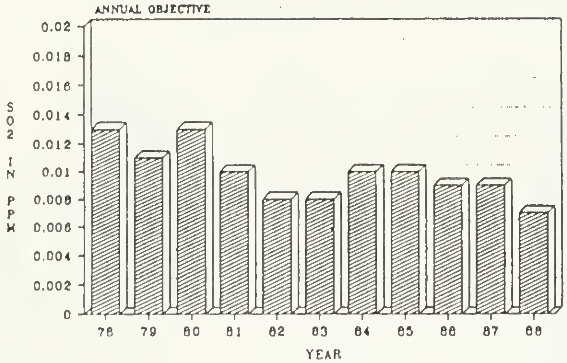
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT GARSON #77065 FROM 1978-1988



PROVINCIAL OBJECTIVE 0.02 PPM (ANNUAL)

FIGURE 8A

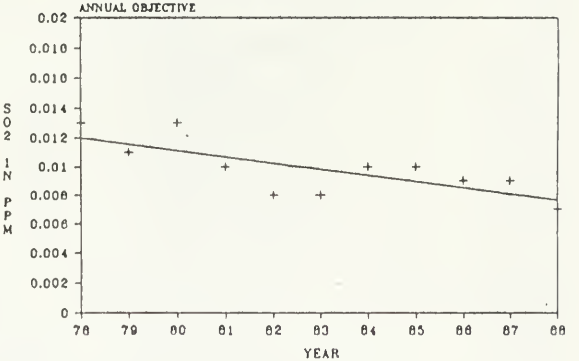
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT NEW SUDBURY #77075, 1978–1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 9

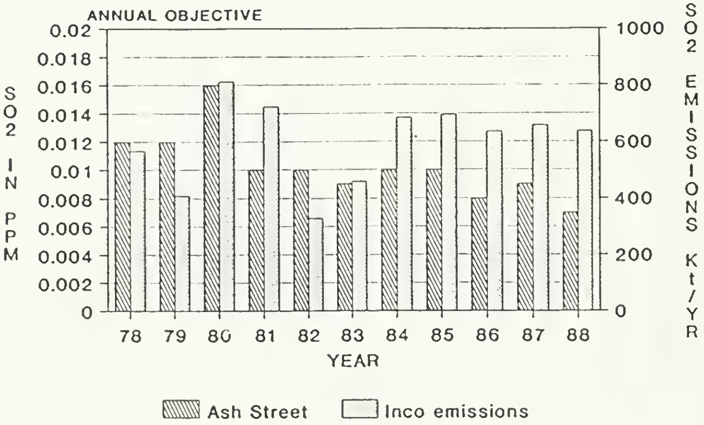
AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT NEW SUDBURY #77075, 1978–1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 9A

AVERAGE ANNUAL CONCENTRATIONS OF SULPHUR DIOXIDE AT ASH ST. #77016 VS INCO EMISSIONS FROM 1978 TO 1988



PROVINCIAL OBJECTIVE: 0.02 PPM (ANNUAL)

FIGURE 10

AVERAGE ANNUAL SO2 AT ASH STREET VS INCO LIMITED EMISSIONS, 1978 TO 1988 LINEAR REGRESSION ANALYSIS

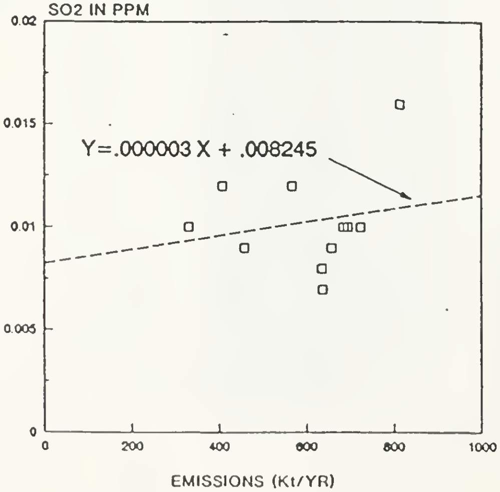
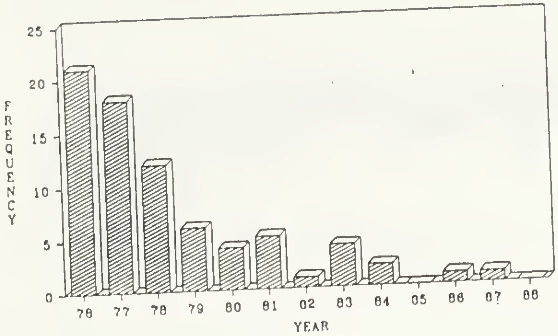


FIGURE 10A

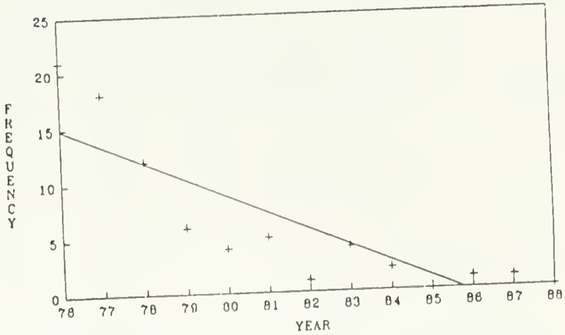
FREQUENCY OVER 0.10 PPM (24-HOUR) SO2
FOR 6 STATIONS* IN SUDBURY, 1976-1988



* = SKEAD(77012), HANMER(77013)
GARSON(77065), ASH ST.(77016)
CONISTON(77026), NEW SUDBURY(77075)

FIGURE 11

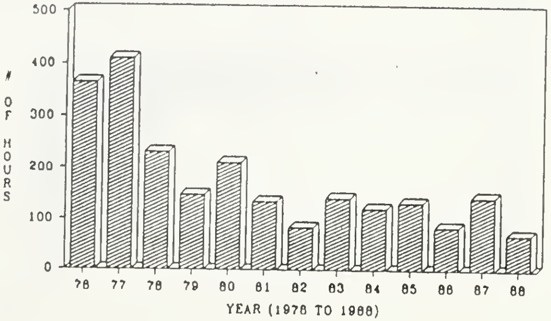
FREQUENCY OVER 0.10 PPM (24-HOUR) SO2
FOR 6 STATIONS* IN SUDBURY, 1976-1988



* = SKEAD(77012), HANMER(77013)
GARSON(77065), ASH ST.(77016)
CONISTON(77026), NEW SUDBURY(77075)

FIGURE 11A

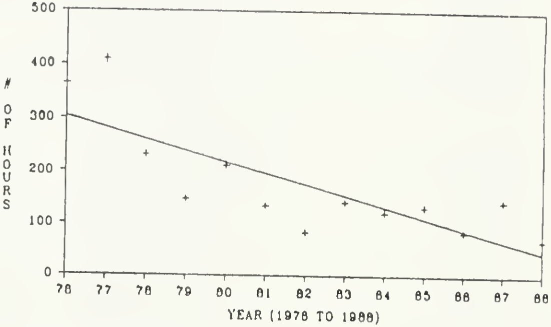
FREQUENCY OVER 0.25 PPM (1-HOUR) SO2
FOR 6 STATIONS* IN SUDBURY 1976-1988



* Skead(77012), Hanmer(77013)
Ash Street(77016), Coniston(77026)
New Sudbury(77075), Garson(77065)

FIGURE 12

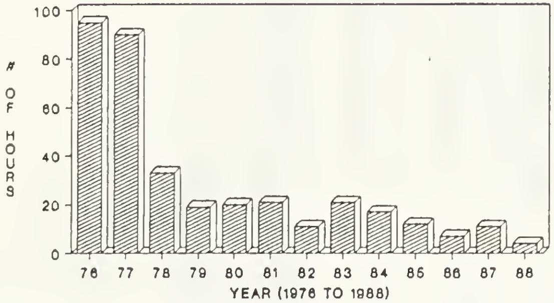
FREQUENCY OVER 0.25 PPM (1-HOUR) SO2
FOR 6 STATIONS* IN SUDBURY 1976-1988



* Skead(77012), Hanmer(77013)
Ash Street(77016), Coniston(77026)
New Sudbury(77075), Garson(77065)

FIGURE 12A

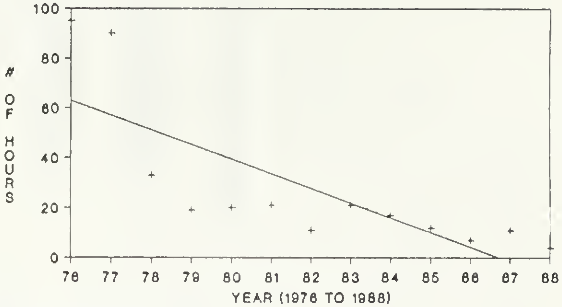
NUMBER OF HOURS GREATER THAN 0.50 PPM OF
SULPHUR DIOXIDE FOR 6 MONITORING SITES•
IN SUDBURY FROM 1976 TO 1988



• Skead(77012), Hanmer(77013)
Ash Street(77016), Coniston(77028)
New Sudbury(77076), Garson(77066)

FIGURE 13

NUMBER OF HOURS GREATER THAN 0.60 PPM OF
SULPHUR DIOXIDE FOR 6 MONITORING SITES•
IN SUDBURY FROM 1976 TO 1988



• Skead(77012), Hanmer(77013)
Ash Street(77016), Coniston(77028)
New Sudbury(77076), Garson(77066)

FIGURE 13A

ANNUAL MEAN NITROGEN DIOXIDE LEVELS -NO2
IN PPM AT ASH STREET #77016 FROM 1978-85
AND AT SCIENCE NORTH FROM 1984 TO 1988

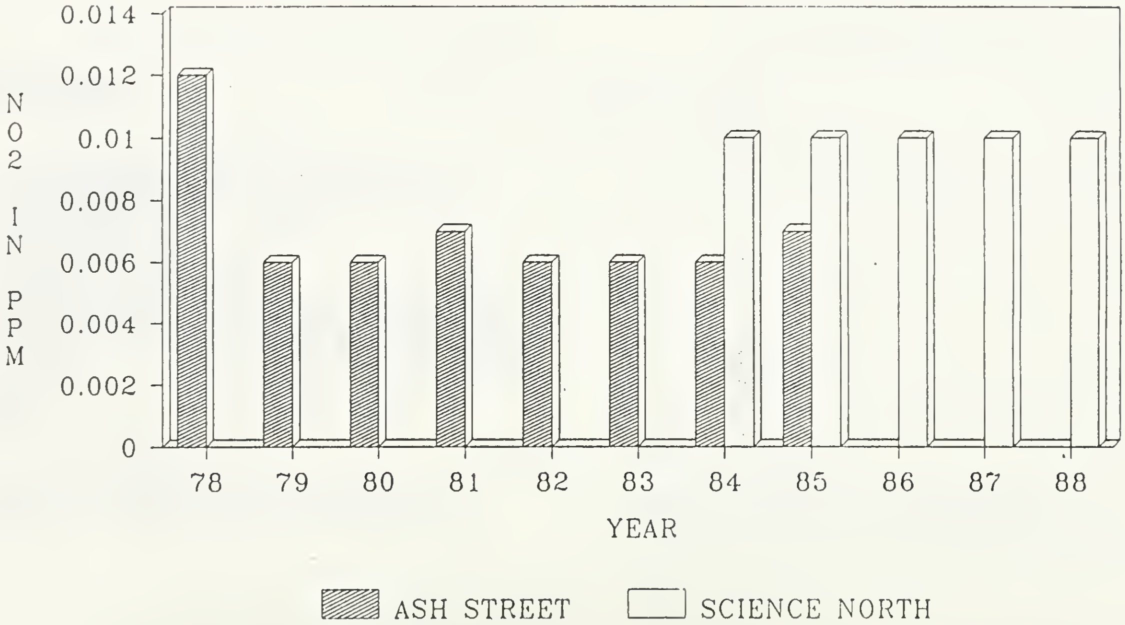


FIGURE 14

ANNUAL MEAN CARBON MONOXIDE (CO) LEVELS
IN PPM AT ASH STREET #77016 FROM 1978-87
AND AT SCIENCE NORTH FROM 1984 TO 1988

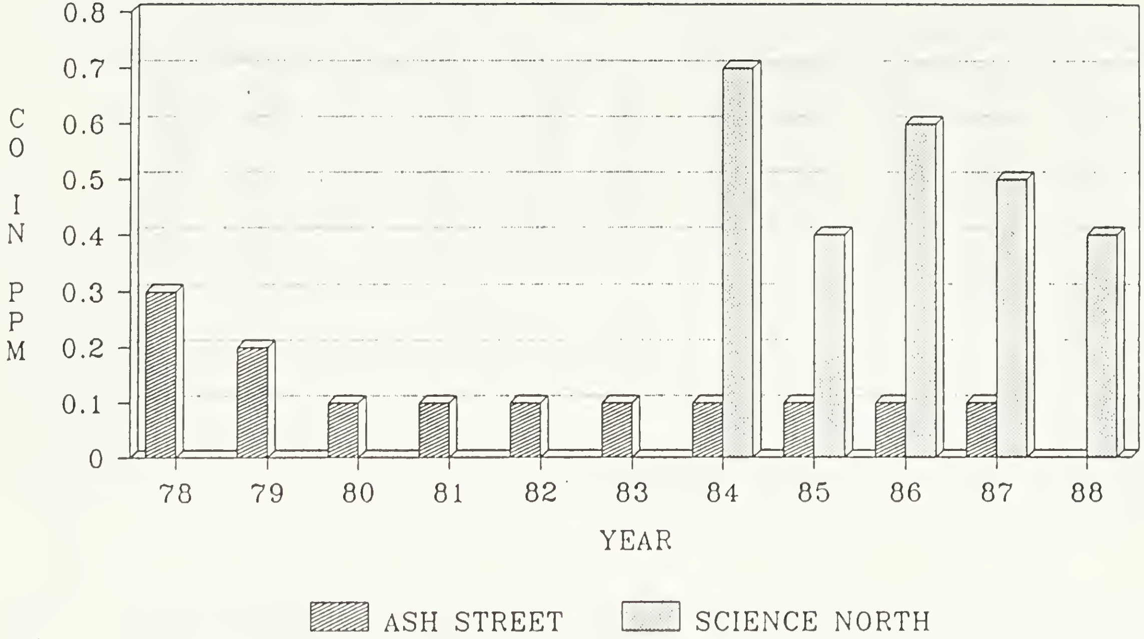


FIGURE 15

ANNUAL MEAN OZONE (O3) LEVELS IN PPB AT ASH STREET #77016 FROM 1978 TO 1988 AND AT SCIENCE NORTH #77203 FROM 1984-1988

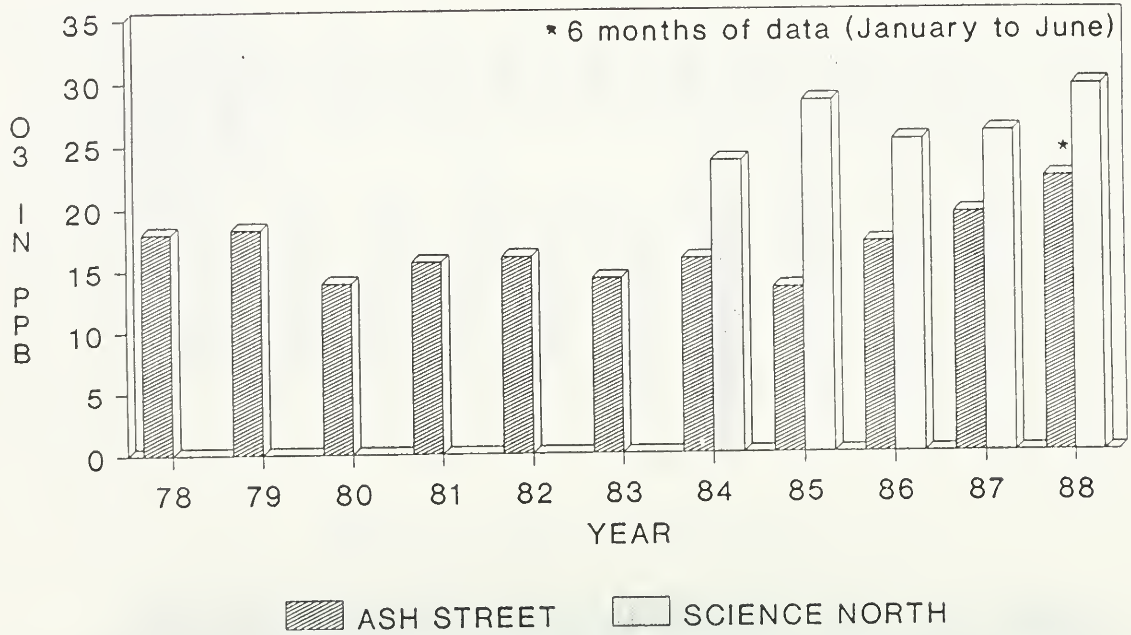
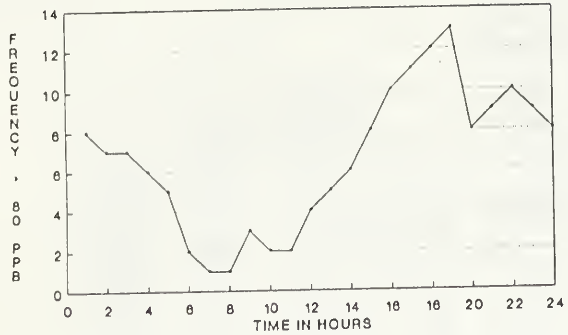


FIGURE 16

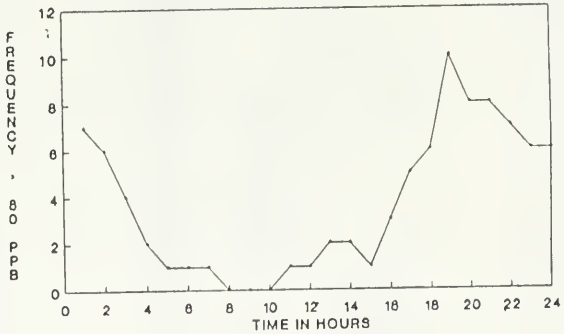
FREQUENCY DISTRIBUTION SHOWING DAILY VARIATIONS OF OZONE GREATER THAN 80 PPB AT SCIENCE NORTH #77203 FROM 1984-88



TOTAL # OF HOURS > 80 PPB: 168 HOURS

FIGURE 17

FREQUENCY DISTRIBUTION SHOWING DAILY VARIATIONS OF OZONE LEVELS GREATER THAN 80 PPB AT ASH STREET #77016 FROM 1978-88



TOTAL # OF HOURS > 80 PPB: 88 HOURS

FIGURE 17A

## ELEVATED OZONE LEVELS IN SUDBURY MEASURED AT SCIENCE NORTH #77203 ON JULY 5th, 6th, AND 7th, 1988

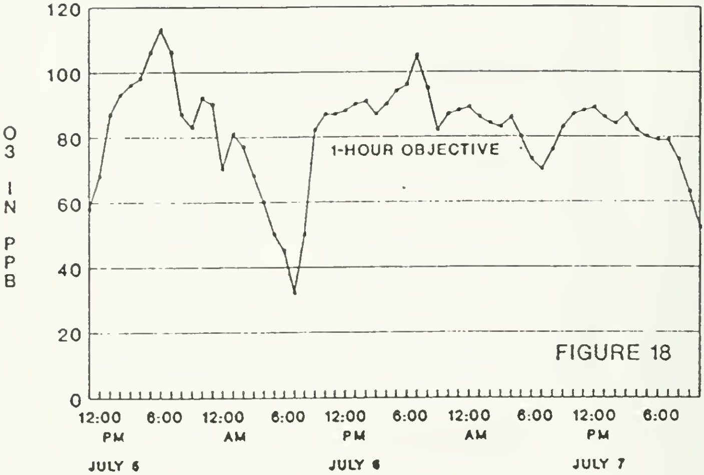


FIGURE 18

## BACK TRAJECTORY ANALYSIS ELEVATED OZONE LEVELS JULY 5th TO 7TH, 1988

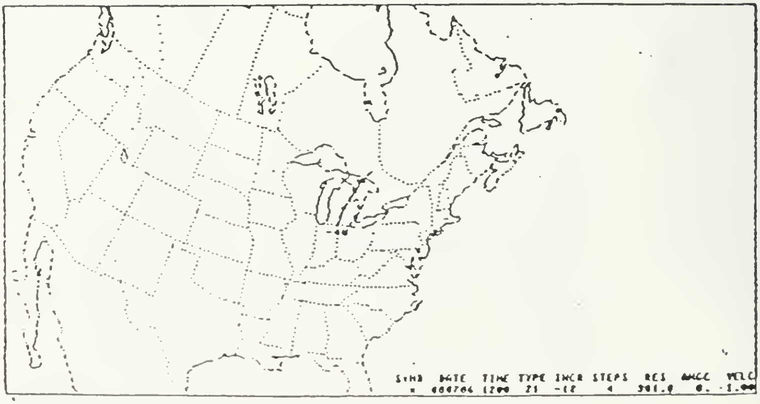
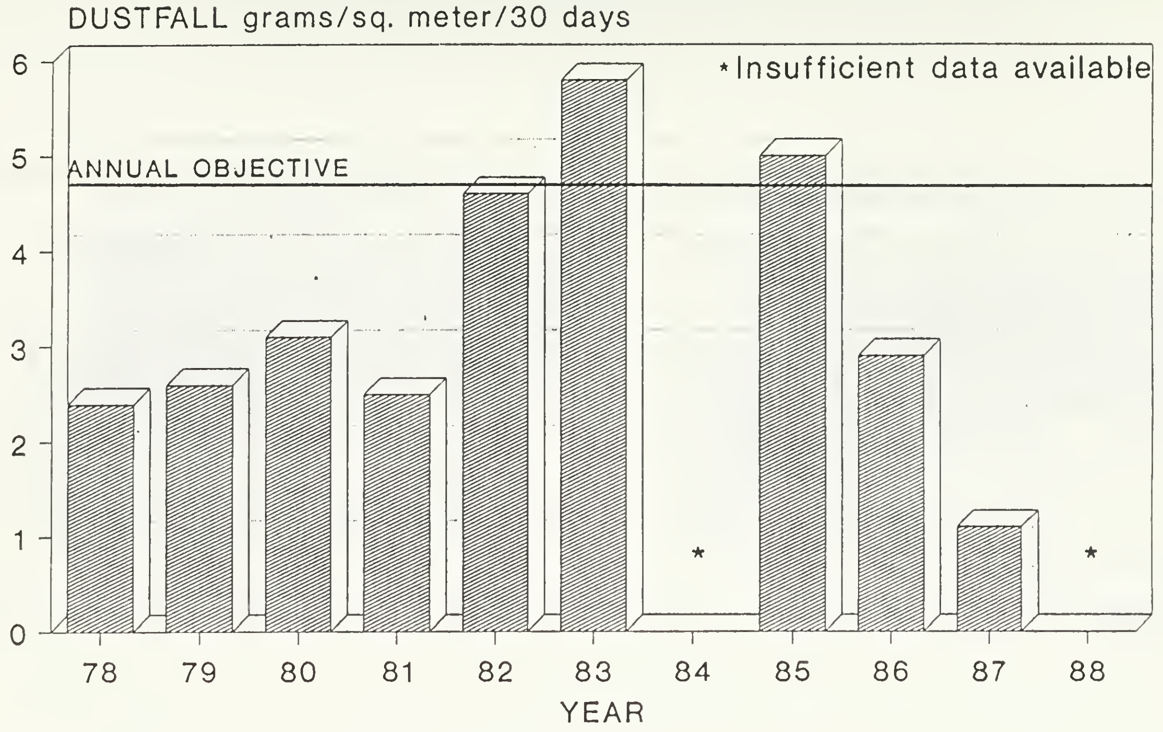


FIGURE 18A

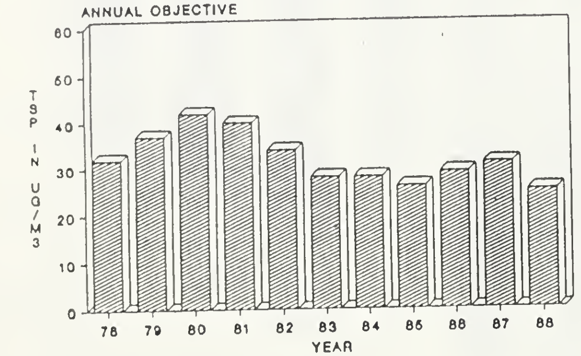
# ANNUAL MEAN DUSTFALL LEVELS IN SUDBURY AT ASH STREET #77016 FROM 1978 TO 1988



ANNUAL OBJECTIVE : 4.6 grams/sq. meter/30 days

FIGURE 19

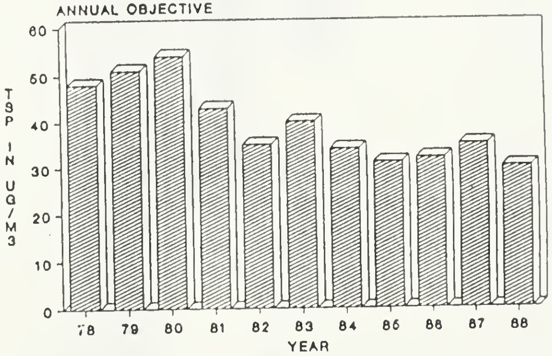
ANNUAL GEOMETRIC MEAN TSP AT
ASH STREET #77016 FROM 1978-88



PROVINCIAL OBJECTIVE: ANNUAL - 60 UG/M3

FIGURE 20

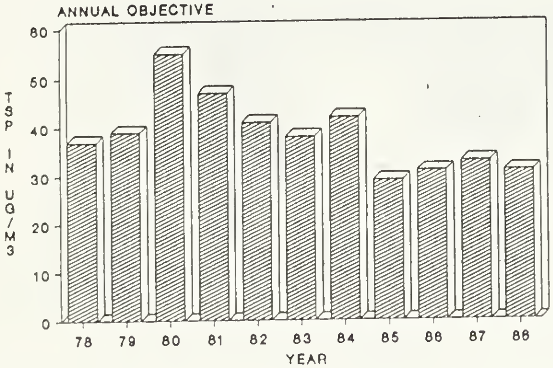
ANNUAL GEOMETRIC MEAN TSP AT
LISGAR ST. #77026, 1978 TO 1988



PROVINCIAL OBJECTIVE: ANNUAL - 60 UG/M3

FIGURE 21

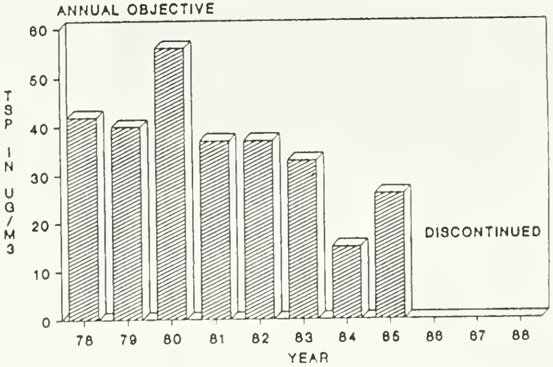
ANNUAL GEOMETRIC MEAN TSP AT
COPPER CLIFF #77070, 1978 TO 1988



PROVINCIAL OBJECTIVE: ANNUAL - 60 UG/M3

FIGURE 22

ANNUAL GEOMETRIC MEAN TSP AT
FALCONBRIDGE #77076, 1978 TO 1985



PROVINCIAL OBJECTIVE: ANNUAL - 60 UG/M3

FIGURE 23

NICKEL (Ni) CONCENTRATIONS IN TSP AT
COPPER CLIFF #77070 IN SUDBURY FROM
1978 TO 1988

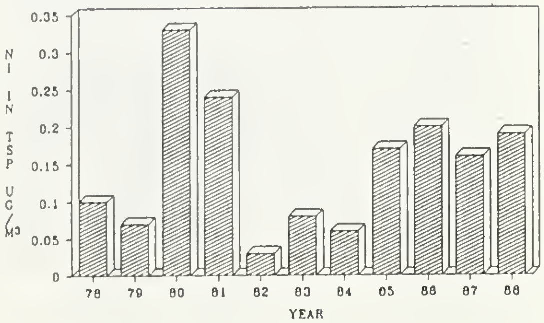


FIGURE 24

COPPER (Cu) CONCENTRATIONS IN TSP AT
COPPER CLIFF #77070 IN SUDBURY FROM
1978 TO 1988

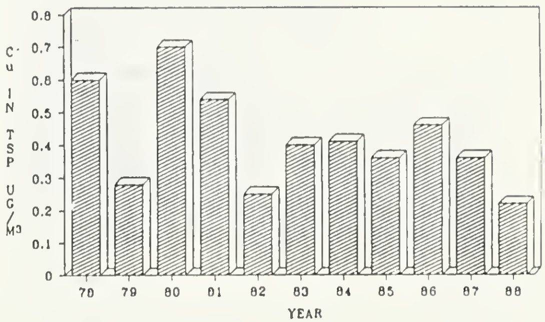
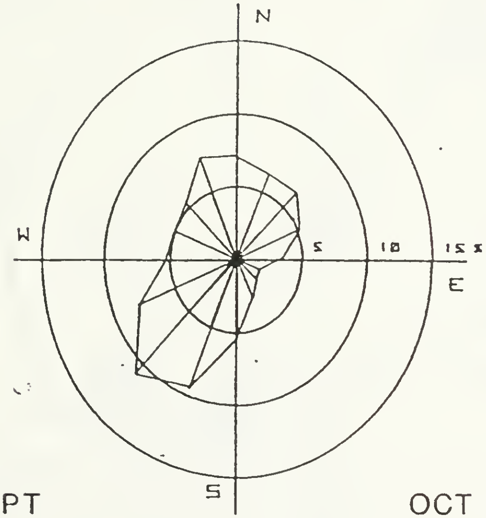


FIGURE 25

# SUDBURY WIND SUMMARY
# 11-YEAR WIND ROSES
# 1978 TO 1988

JANUARY TO DECEMBER

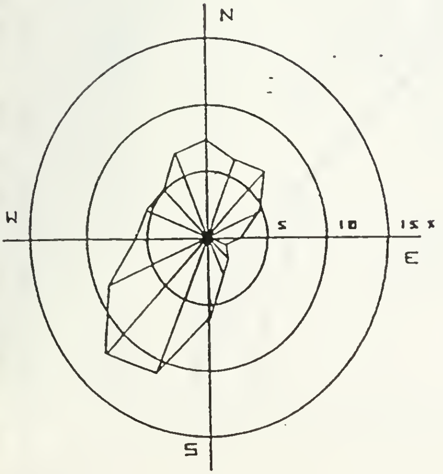


WS1 - 10 meters

% Calm (< 4 km/hr)

= 8.0 %

APRIL TO SEPT



OCT TO MARCH

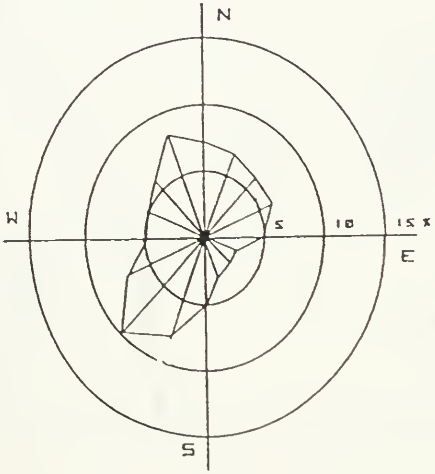


FIGURE 26

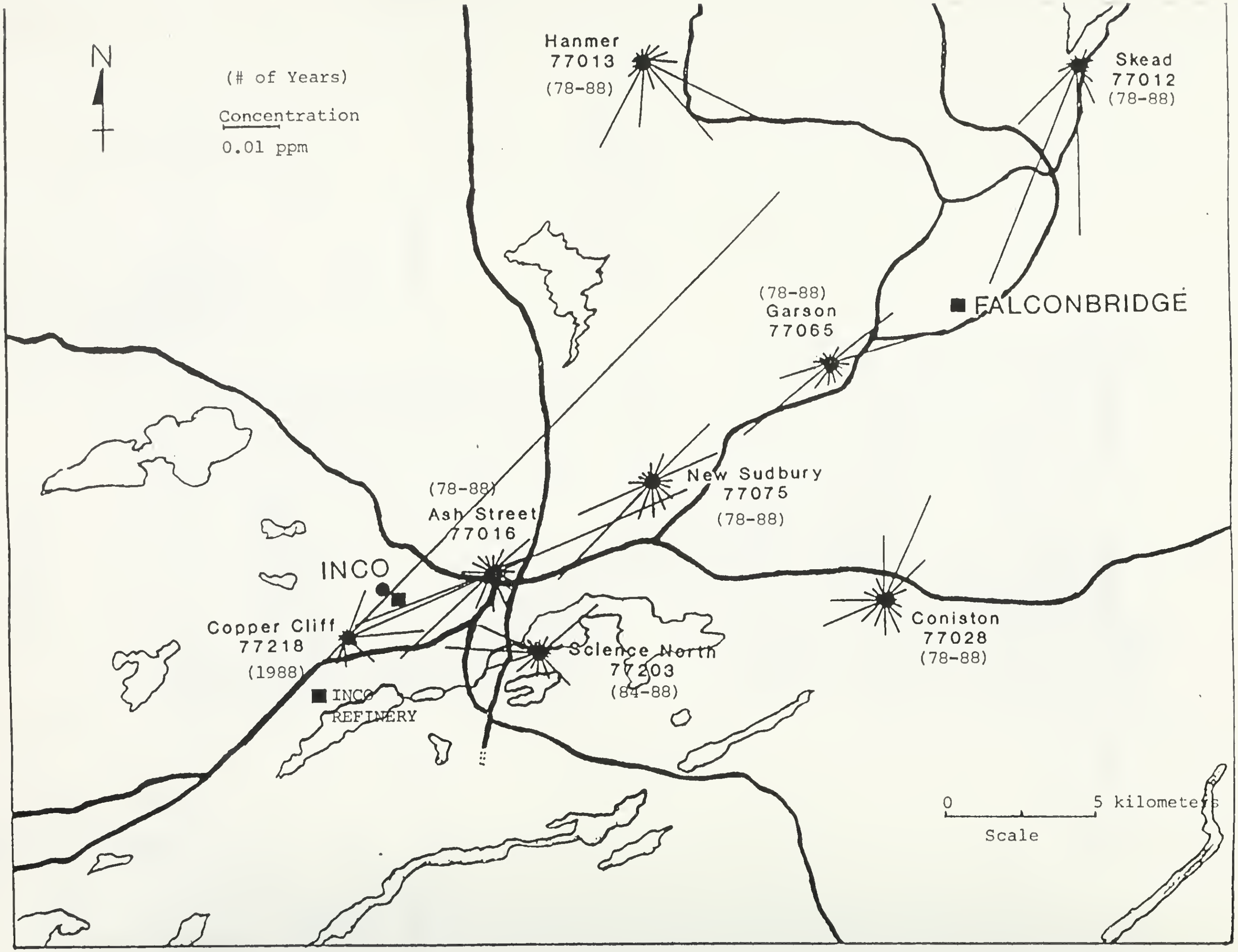


Figure 27. Sulphur Dioxide Pollution Roses

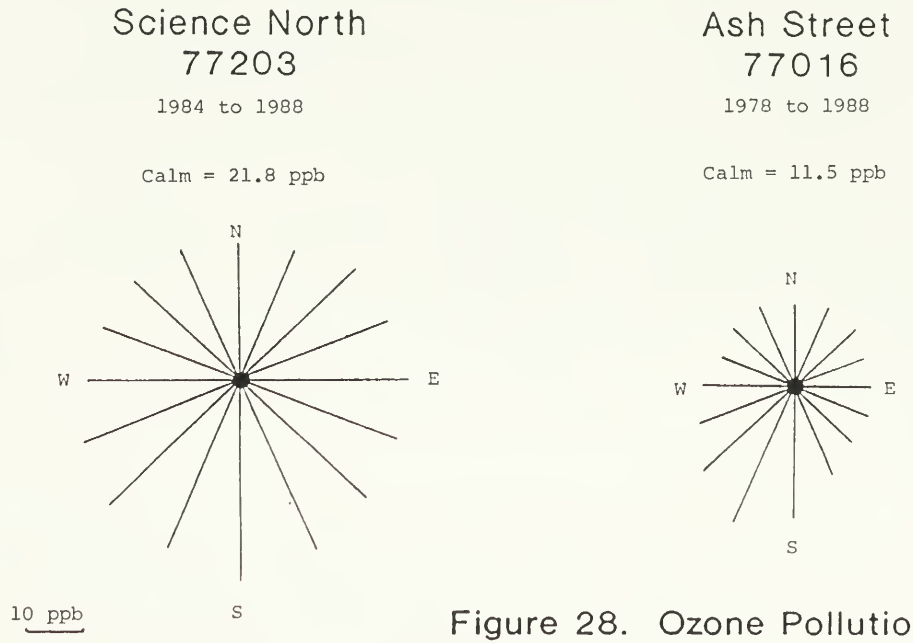


Figure 28. Ozone Pollution Roses

# TABLES

## TABLE 1

## SUDBURY AMBIENT AIR MONITORING LOCATIONS - 1978 TO 1988

| STATION | NO. | AQI | API | $SO_2$ | SULP | $O_3$ | CO | NOX | TRS | COH | TSP | DUST | MET |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lake Penage | 77001 | | | X | | | | | | | | | |
| Burwash | 77009 | | | X | | | | | | | | | |
| Callum | 77010 | | | X | | | | | | | | | |
| Skead | 77012 | | | X | | | | | | | | | |
| Hanmer | 77013 | | | X | | | | | | | | | W |
| Rayside (Old) | 77014 | | | X | | | | | | | | | |
| Ash Street | 77016 | | X | X | X | X | X | X | | X | X | X | |
| Morgan | 77017 | | | X | | | | | | | | | |
| St. Charles | 77018 | | | X | | | | | | | | | |
| Grassy Lake | 77019 | | | X | | | | | | | | | |
| Happy Valley | 77023 | | | X | | | | | | | | | |
| Lisgar Street | 77026 | | | | X | | | | | X | X | X | |
| Coniston | 77028 | | X | X | | | | | | X | | | |
| CKNC (Frood Road) | 77025 | | | | | | | | | | | | W/T |
| Auger Avenue | 77030 | | | | X | | | | | | | X | |
| Williams Avenue | 77034 | | | | X | | | | | | | | |
| LaForest Avenue | 77036 | | | | X | | | | | | | | |
| Marion/McNau. Sts. | 77037 | | | | X | | | | | | | | |
| Ramsey Lake Road | 77038 | | | | X | | | | | | | | |
| Southview Drive | 77039 | | | | | | | | | | | X | |
| Tuddenham Avenue | 77040 | | | | | | | | | | | X | |
| Second Avenue | 77041 | | | | | | | | | | | X | |
| Oliver St (C.Cliff) | 77043 | | | | | | | | | | | X | |
| Penman Avenue | 77049 | | | | | | | | | | | X | |
| Hwy. 17 (C. Cliff) | 77051 | | | | | | | | | | | X | |
| Lockerby | 77052 | | | X | | | | | | | | | |

Continued....

## TABLE 1 (Continued)

## SUDBURY AMBIENT AIR MONITORING LOCATIONS - 1978 TO 1988

| STATION | NO. | AQI | API | $SO_2$ | SULP | $O_3$ | CO | NOX | TRS | COH | TSP | DUST | MET |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Garson | 77065 | | | X | | | | | | | | | |
| Lake Temagami | 77066 | | | X | | | | | | | | | |
| Chiniuchi Lake | 77067 | | | X | | | | | | | | | |
| Copper Cliff | 77070 | | | | | | | | | | X | | |
| New Sudbury | 77075 | | X | X | | | | | | X | | | |
| Falconbridge | 77076 | | | | | | | | | | X | | |
| Glover Street | 77078 | | | | | | | | | | | X | |
| Kelly Lake Road | 77082 | | | | | | | | | | | X | |
| Southview/Indust. | 77083 | | | | | | | | | | | X | |
| Indust.Rd.(Junc.Cr) | 77084 | | | | | | | | | | | X | |
| Falc. Hyw. (Garson) | 77089 | | | | | | | | | | | X | |
| Laurentian Hospital | 77092 | | | X | | | | | | | | | |
| Long Lake | 77096 | | | X | | | | | | | | | |
| Old Falconbridge Rd | 77200 | | | | | | | | | | | X | |
| Mikkola | 77201 | | | X | | | | | | | | | |
| Science North | 77203 | X | X | X | | X | X | X | X | X | | | |
| Rayside (New) | 77206 | | | X | | | | | | | | | |
| Spruce/Travers St. | 77211 | | | | | | | | | | | X | |
| Copper Cliff | 77218 | | | X | | | | | | | | | |
| Verner | 75016 | | | X | | | | | | | | | |

Legend

AQI - Air Quality Index
API - Air Pollution Index
$SO_2$ - Sulphur Dioxide
Sulp - Sulphation Rate
$O_3$ - Ozone
CO - Carbon Monoxide
NOx - Oxides of Nitrogen ($NO_2$ & NO)

TRS - Total Reduced Sulphurs
COH - Coefficient of Haze
TSP - Total Suspended Particulates
Dust - Dustfall
Met - Meteorological Data
W - Wind Speed and Direction
T - Temperature

## TABLE 2

## SULPHUR DIOXIDE EMISSIONS FROM INCO LIMITED AND FALCONBRIDGE LIMITED IN SUDBURY FROM 1978 TO 1988

### $SO_2$ EMISSIONS IN THOUSANDS OF TONNES PER YEAR ($10^3$)

| YEAR | INCO | FALCONBRIDGE | TOTAL |
|---|---|---|---|
| 1978***(strike year - Inco) | 567 | 117 | 684 |
| 1979***(strike year - Inco) | 408 | 88 | 496 |
| 1980***(Falconbridge shutdown) | 812 | 123 | 935 |
| 1981* | 724 | 113 | 837 |
| 1982* (major shutdown - Inco (9 months) & Falconbridge (6 months) | 329 | 61 | 390 |
| 1983+ | 459 | 79 | 538 |
| 1984+ | 685 | 85 | 770 |
| 1985+ | 695 | 74 | 769 |
| 1986+ | 635 | 85 | 720 |
| 1987+ | 658 | 65 | 723 |
| 1988+ | 637 | 65 | 702 |

* Summer Vacation shutdown (Inco and Falconbridge)

*** Production shutdown

+ 3-week summer shutdown (Inco and Falconbridge)

## TABLE 3

## COMMISSIONING, DECOMMISSIONING, AND/OR RELOCATION OF $SO_2$ MONITORING STATION IN SUDBURY FROM 1978 TO 1988

| STATION | STATION NUMBER | COMMISSIONED | DECOMMISSIONED |
|---|---|---|---|
| Lake Penage | 77001 | 1970 | September 1981 |
| Morgan | 77017 | 1970 | June 1980 |
| St. Charles | 77018 | 1970 | January 1984 |
| Grassy Lake | 77019 | 1970 | October 1979 |
| Happy Valley | 77023 | 1970 | August 1982 |
| Lockerby | 77052 | 1975 | June 1980 |
| Chiniguchi Lake | 77067 | 1975 | October 1981 |
| Garson | 77065 | 1970 | Continues to operate |
| Burwash | 77009 | 1970 | February 1986 |
| Callum | 77010 | 1970 | February 1986 |
| Skead | 77012 | 1970 | Continues to operate |
| Hanmer | 77013 | 1973 | June 1985 |
| Rayside (Old) | 77014 | 1970 | Continues to operate |
| Ash Street | 77016 | 1970 | Continues to operate |
| Coniston | 77028 | 1974 | Continues to operate |
| New Sudbury | 77075 | 1976 | Continues to operate |
| Verner | 75016 | 1971 | May 1980 |
| Lake Temagami | 77066 | 1975 | June 1986 |
| Long Lake | 77096 | 1980 | Continues to operate |
| Laurentian Hospital | 77092 | 1980 | July 1984 |
| Mikkola | 77201 | 1982 | Continues to operate |
| Science North | 77203 | 1984 | Continues to operate |
| Rayside (New) | 77206 | 1985 | Continues to operate |
| Copper Cliff | 77218 | 1987 | Continues to operate |

## TABLE 4

## ANNUAL MEAN $SO_2$ LEVELS FOR MONITORING STATIONS IN THE SUDBURY AREA FROM 1978 TO 1988

| STATION | STATION NUMBER | AVERAGE ANNUAL CONCENTRATION (PPM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lake Penage | 77001 | .004 | .001 | .004 | .003 | - | - | - | - | - | - | - |
| Burwash | 77009 | .005 | .004 | .006 | .005 | .004 | .004 | .006 | .005 | - | - | - |
| Callum | 77010 | .005 | .003 | .006 | .004 | .003 | .003 | .005 | .004 | - | - | - |
| Skead | 77012 | .011 | .012 | .011 | .011 | .008 | .010 | .011 | .010 | .009 | .010 | .008 |
| Hanmer | 77013 | .006 | .005 | .007 | .006 | .004 | .006 | .009 | .008 | .005 | .006 | .005 |
| Rayside (Old) | 77014 | .003 | .003 | .004 | .004 | .003 | .003 | .005 | .004 | - | - | - |
| Garson | 77065 | .009 | .007 | .009 | .008 | .009 | .009 | .008 | .009 | .008 | .008 | .007 |
| Ash Street | 77016 | .012 | .012 | .016 | .010 | .010 | .009 | .010 | .010 | .008 | .009 | .007 |
| Morgan | 77017 | .002 | .003 | - | - | - | - | - | - | - | - | - |
| St. Charles | 77018 | .005 | .002 | .004 | .003 | .002 | .002 | - | - | - | - | - |
| Coniston | 77028 | .013 | .010 | .014 | .011 | .006 | .006 | .008 | .007 | .006 | .008 | .005 |
| Lockerby | 77052 | .006 | .006 | - | - | - | - | - | - | - | - | - |
| New Sudbury | 77075 | .013 | .011 | .013 | .010 | .008 | .008 | .010 | .010 | .009 | .009 | .007 |
| Verner | 75016 | .002 | .002 | .003 | - | - | - | - | - | - | - | - |
| Grassy Lake* | 77019 | .003 | .002 | - | - | - | - | - | - | - | - | - |
| Chiniguchi Lake* | 77067 | .005 | .003 | .004 | - | - | - | - | - | - | - | - |
| Lake Temagami* | 77066 | .002 | .002 | .004 | .004 | .003 | .002 | .002 | .003 | - | - | - |
| Laurentian Hospital | 77092 | - | - | .008 | .005 | .004 | .008 | .010 | - | - | - | - |
| Long Lake | 77096 | - | - | .014 | .007 | .005 | .007 | .009 | .007 | .007 | .009 | .007 |
| Happy Valley | 77023 | .019 | .022 | .020 | .019 | .019 | - | - | - | - | - | - |
| Mikkola | 77201 | - | - | - | - | .002 | .006 | .009 | .007 | .007 | .009 | .006 |
| Science North | 77203 | - | - | - | - | - | - | .010 | .009 | .007 | .008 | .009 |
| Rayside (St. Laur.) | 77206 | - | - | - | - | - | - | - | .005 | .004 | .004 | .003 |
| Copper Cliff | 77218 | - | - | - | - | - | - | - | - | - | .011 | .019 |

* Indicates Stations that operated during the growing season only

## TABLE 5

## SULPHUR DIOXIDE ($SO_2$) FREQUENCY OF EXCEEDANCE OF THE 24-HOUR PROVINCIAL OBJECTIVE (0.10 PPM) IN THE SUDBURY AREA FROM 1978 TO 1988

| STATION | STATION NUMBER | FREQUENCY ABOVE 24-HOUR OBJECTIVE (0.10 PPM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lake Penage | 77001 | 0 | 0 | 0 | 0 | - | - | - | - | - | - | - |
| Burwash | 77009 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - |
| Callum | 77010 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - |
| Skead | 77012 | 5 | 3 | 3 | 4 | 0 | 2 | 0 | 0 | 1 | 0 | 0 |
| Hanmer | 77013 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Rayside (old) | 77014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - |
| Garson | 77065 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Ash Street | 77016 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Morgan | 77017 | 0 | 0 | - | - | - | - | - | - | - | - | - |
| Coniston | 77028 | 4 | 2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| Lockerby | 77052 | 3 | 0 | - | - | - | - | - | - | - | - | - |
| New Sudbury | 77075 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Verner | 75016 | 0 | 0 | 0 | - | - | - | - | - | - | - | - |
| Grassy Lake* | 77019 | 0 | 0 | - | - | - | - | - | - | - | - | - |
| St. Charles | 77018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - | - |
| Chiniguchi Lake* | 77067 | 0 | 0 | 0 | - | - | - | - | - | - | - | - |
| Lake Temagami* | 77066 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | - | - | - |
| Laurentian Hosp. | 77092 | - | - | 1 | 1 | 0 | 1 | 0 | - | - | - | - |
| Long Lake | 77096 | - | - | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 1 |
| Happy Valley | 77023 | 9 | 22 | 12 | 13 | 6 | - | - | - | - | - | - |
| Mikkola | 77201 | - | - | - | - | 0 | 0 | 3 | 2 | 3 | 3 | 1 |
| Science North | 77203 | - | - | - | - | - | - | 0 | 1 | 0 | 0 | 0 |
| Rayside (New) | 77206 | - | - | - | - | - | - | - | 0 | 0 | 0 | 0 |
| Copper Cliff | 77218 | - | - | - | - | - | - | - | - | - | 1 | 6 |

* Indicates Stations that operated during the growing season only

## TABLE 5A

## SULPHUR DIOXIDE ($SO_2$) FREQUENCY OF EXCEEDANCE OF THE 1-HOUR (0.25 PPM) PROVINCIAL OBJECTIVE IN THE SUDBURY AREA FROM 1978 TO 1988

| STATION | STATION NUMBER | FREQUENCY ABOVE 1-HOUR OBJECTIVE (0.25 PPM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lake Penage | 77001 | 6 | 0 | 9 | 6 | - | - | - | - | - | - | - |
| Burwash | 77009 | 9 | 2 | 5 | 1 | 8 | 1 | 8 | 2 | - | - | - |
| Callum | 77010 | 4 | 2 | 9 | 2 | 1 | 1 | 7 | 2 | - | - | - |
| Skead | 77012 | 84 | 64 | 58 | 64 | 32 | 45 | 34 | 36 | 32 | 29 | 18 |
| Hanmer | 77013 | 12 | 7 | 23 | 9 | 7 | 9 | 13 | 18 | 6 | 13 | 6 |
| Rayside (Old) | 77014 | 5 | 8 | 6 | 5 | 3 | 5 | 6 | 3 | - | - | - |
| Garson | 77065 | 28 | 35 | 32 | 16 | 22 | 29 | 22 | 11 | 18 | 24 | 9 |
| Ash Street | 77016 | 22 | 7 | 19 | 13 | 2 | 18 | 14 | 29 | 6 | 19 | 17 |
| Morgan | 77017 | 1 | 1 | - | - | - | - | - | - | - | - | - |
| Coniston | 77028 | 50 | 12 | 54 | 16 | 15 | 20 | 20 | 12 | 4 | 24 | 8 |
| Lockerby | 77052 | 25 | 7 | - | - | - | - | - | - | - | - | - |
| New Sudbury | 77075 | 36 | 22 | 25 | 16 | 6 | 20 | 18 | 26 | 19 | 34 | 12 |
| Verner | 75016 | 3 | 1 | 0 | - | - | - | - | - | - | - | - |
| Grassy Lake* | 77019 | 0 | 2 | - | - | - | - | - | - | - | - | - |
| St. Charles | 77018 | 0 | 0 | 0 | 0 | 0 | 4 | - | - | - | - | - |
| Chiniguchi Lake* | 77067 | 0 | 0 | 0 | - | - | - | - | - | - | - | - |
| Lake Temagami* | 77066 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | - | - | - |
| Laurentian Hosp. | 77092 | - | - | 10 | 17 | 2 | 15 | 5 | - | - | - | - |
| Long Lake | 77096 | - | - | 1 | 20 | 9 | 22 | 13 | 26 | 18 | 36 | 22 |
| Happy Valley | 77023 | 130 | 212 | 160 | 166 | 58 | - | - | - | - | - | - |
| Mikkola | 77201 | - | - | - | - | 2 | 15 | 37 | 29 | 29 | 32 | 23 |
| Science North | 77203 | - | - | - | - | - | - | 16 | 36 | 13 | 12 | 30 |
| Rayside (St. Laur.) | 77206 | - | - | - | - | - | - | - | 2 | 10 | 18 | 9 |
| Copper Cliff | 77218 | - | - | - | - | - | - | - | - | - | 13 | 85 |

* Indicates Stations that operated during the growing season only

## TABLE 5B

## SULPHUR DIOXIDE ($SO_2$) FREQUENCY OF EXCEEDANCE OF THE 1-HOUR CONTROL ORDER LIMIT (0.50 PPM) IN THE SUDBURY AREA FROM 1978 TO 1988

| STATION | STATION NUMBER | FREQUENCY ABOVE 1-HOUR LIMIT (0.50 PPM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lake Penage | 77001 | 1 | 0 | 0 | 0 | - | - | - | - | - | - | - |
| Burwash | 77009 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | - | - | - |
| Callum | 77010 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | - | - | - |
| Skead | 77012 | 12 | 11 | 7 | 13 | 2 | 1 | 3 | 5 | 2 | 2 | 2 |
| Hanmer | 77013 | 4 | 0 | 4 | 0 | 1 | 0 | 3 | 2 | 1 | 1 | 1 |
| Rayside (old) | 77014 | 4 | 2 | 0 | 3 | 0 | 0 | 2 | 0 | - | - | - |
| Garson | 77065 | 2 | 3 | 2 | 3 | 3 | 9 | 6 | 1 | 3 | 2 | 0 |
| Ash Street | 77016 | 2 | 1 | 0 | 0 | 0 | 3 | 2 | 2 | 1 | 2 | 0 |
| Morgan | 77017 | 0 | 0 | - | - | - | - | - | - | - | - | - |
| Coniston | 77028 | 10 | 1 | 5 | 4 | 4 | 2 | 3 | 1 | 0 | 1 | 0 |
| Lockerby | 77052 | 16 | 1 | - | - | - | - | - | - | - | - | - |
| New Sudbury | 77075 | 3 | 4 | 1 | 1 | 1 | 6 | 0 | 1 | 0 | 3 | 1 |
| Verner | 75016 | 0 | 0 | 0 | - | - | - | - | - | - | - | - |
| Grassy Lake* | 77019 | 0 | 0 | - | - | - | - | - | - | - | - | - |
| St. Charles | 77018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | - | - |
| Chiniguchi Lake* | 77067 | 0 | 0 | 0 | - | - | - | - | - | - | - | - |
| Lake Temagami* | 77066 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | - | - | - |
| Laurentian Hosp. | 77092 | - | - | 1 | 6 | 0 | 2 | 0 | - | - | - | - |
| Long Lake | 77096 | - | - | 1 | 2 | 2 | 3 | 3 | 6 | 1 | 11 | 5 |
| Happy Valley | 77023 | 60 | 85 | 33 | 55 | 21 | - | - | - | - | - | - |
| Mikkola | 77201 | - | - | - | - | 0 | 6 | 6 | 5 | 2 | 3 | 1 |
| Science North | 77203 | - | - | - | - | - | - | 3 | 12 | 0 | 2 | 7 |
| Rayside (New) | 77206 | - | - | - | - | - | - | - | 0 | 1 | 1 | 1 |
| Copper Cliff | 77218 | - | - | - | - | - | - | - | - | - | 0 | 29 |

* Indicates Stations that operated during the growing season only

## TABLE 6

## 24-HOUR MAXIMUM $SO_2$ CONCENTRATIONS IN THE SUDBURY AREA FROM 1978 TO 1988

| STATION | STATION NUMBER | 24-HOUR MAXIMUM CONCENTRATION (PPM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lake Penage | 77001 | .07 | .07 | .08 | .10 | - | - | - | - | - | - | - |
| Burwash | 77009 | .10 | .05 | .08 | .05 | .06 | .05 | .08 | .06 | - | - | - |
| Callum | 77010 | .05 | .03 | .06 | .04 | .03 | .03 | .06 | .04 | - | - | - |
| Skead | 77012 | .16 | .16 | .12 | .19 | .09 | .23 | .09 | .09 | .12 | .10 | .07 |
| Hanmer | 77013 | .08 | .07 | .09 | .08 | .10 | .08 | .11 | .07 | .06 | .09 | .09 |
| Rayside (Old) | 77014 | .10 | .09 | .07 | .08 | .06 | .09 | .08 | .04 | - | - | - |
| Garson | 77065 | .10 | .09 | .09 | .11 | .10 | .14 | .10 | .08 | .09 | .11 | .06 |
| Ash Street | 77016 | .11 | .09 | .09 | .09 | .05 | .15 | .08 | .10 | .06 | .09 | .09 |
| Morgan | 77017 | .06 | .05 | - | - | - | - | - | - | - | - | - |
| Coniston | 77028 | .18 | .11 | .11 | .09 | .17 | .08 | .11 | .08 | .06 | .09 | .07 |
| Lockerby | 77052 | .19 | .06 | - | - | - | - | - | - | - | - | - |
| New Sudbury | 77075 | .19 | .11 | .10 | .09 | .09 | .32 | .07 | .10 | .07 | .09 | .08 |
| Verner | 75016 | .03 | .06 | .02 | - | - | - | - | - | - | - | - |
| Grassy Lake* | 77019 | .03 | .02 | - | - | - | - | - | - | - | - | - |
| St. Charles | 77018 | .03 | .03 | .05 | .03 | .03 | .10 | - | - | - | - | - |
| Chiniguchi Lake* | 77067 | .05 | .03 | .03 | - | - | - | - | - | - | - | - |
| Lake Temagami* | 77066 | .02 | .03 | .03 | .05 | .11 | .03 | .02 | .02 | - | - | - |
| Laurentian Hosp. | 77092 | - | - | .11 | .13 | .05 | .12 | .06 | - | - | - | - |
| Long Lake | 77096 | - | - | .08 | .09 | .09 | .14 | .11 | .10 | .08 | .27 | .12 |
| Happy Valley | 77023 | .57 | .49 | .33 | .32 | .25 | - | - | - | - | - | - |
| Mikkola | 77201 | - | - | - | - | .04 | .10 | .19 | .13 | .13 | .15 | .14 |
| Science North | 77203 | - | - | - | - | - | - | .08 | .19 | .08 | .09 | .10 |
| Rayside (St. Laur.) | 77206 | - | - | - | - | - | - | - | .07 | .10 | .06 | .06 |
| Copper Cliff | 77218 | - | - | - | - | - | - | - | - | - | .15 | .31 |

* Indicates Stations that operated during the growing season only

## TABLE 6A

## 1-HOUR MAXIMUM $SO_2$ CONCENTRATIONS IN THE SUDBURY AREA FROM 1978 TO 1988

| STATION | STATION NUMBER | 1-HOUR MAXIMUM CONCENTRATION (PPM) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lake Penage | 77001 | .42 | .25 | .43 | .44 | - | - | - | - | - | - | - |
| Burwash | 77009 | .39 | .29 | .41 | .27 | .41 | .32 | .65 | .29 | - | - | - |
| Callum | 77010 | .34 | .32 | .54 | .39 | .45 | .44 | .52 | .29 | - | - | - |
| Skead | 77012 | .90 | .83 | .85 | .91 | .62 | .58 | .57 | .81 | .56 | .81 | .67 |
| Hanmer | 77013 | .55 | .49 | .64 | .38 | .54 | .41 | .90 | .78 | .67 | .72 | .83 |
| Rayside (old) | 77014 | .75 | .81 | .48 | .67 | .31 | .45 | .85 | .30 | - | - | - |
| Garson | 77065 | .69 | .61 | .87 | .76 | .69 | .97 | .92 | .47 | .65 | .61 | .38 |
| Ash Street | 77016 | 1.02 | .43 | .56 | .44 | .33 | .67 | .83 | .64 | .55 | .98 | .49 |
| Morgan | 77017 | .35 | .39 | - | - | - | - | - | - | - | - | - |
| Coniston | 77028 | .91 | .52 | 1.07 | .77 | 1.12 | .56 | .60 | .59 | .28 | .51 | .50 |
| Lockerby | 77052 | .75 | .71 | - | - | - | - | - | - | - | - | - |
| New Sudbury | 77075 | 1.77 | .76 | .51 | .56 | .51 | 1.67 | .47 | .66 | .49 | .80 | .54 |
| Verner | 75016 | .33 | .32 | .14 | - | - | - | - | - | - | - | - |
| Grassy Lake* | 77019 | .18 | .16 | - | - | - | - | - | - | - | - | - |
| St. Charles | 77018 | .23 | .15 | .20 | .20 | .19 | .47 | - | - | - | - | - |
| Chiniguchi Lake* | 77067 | .25 | .21 | .20 | - | - | - | - | - | - | - | - |
| Lake Temagami* | 77066 | .16 | .22 | .18 | .18 | .58 | .10 | .20 | .21 | - | - | - |
| Laurentian Hosp. | 77092 | - | - | .60 | .74 | .27 | .56 | .34 | - | - | - | - |
| Long Lake | 77096 | - | - | .29 | .57 | .55 | 1.21 | .79 | .65 | .58 | .98 | .70 |
| Happy Valley | 77023 | 1.65 | 1.86 | 1.73 | 1.39 | 1.78 | - | - | - | - | - | - |
| Mikkola | 77201 | - | - | - | - | .36 | .57 | .99 | .80 | .74 | .65 | .66 |
| Science North | 77203 | - | - | - | - | - | - | .84 | .92 | .46 | .70 | .80 |
| Rayside (St.Laur.) | 77206 | - | - | - | - | - | - | - | .39 | .56 | .60 | .54 |
| Copper Cliff | 77218 | - | - | - | - | - | - | - | - | - | .59 | 1.24 |

* Indicates Stations that operated during the growing season only

## TABLE 7

## 1-HOUR AND 24-HOUR $SO_2$ FREQUENCY OF EXCEEDANCES

| STATION NAME | STATION NUMBER | >0.10 (24-HOUR) 1978-1983 | >0.10 (24-HOUR) 1984-1988 | >0.25 (1-HOUR) 1978-1983 | >0.25 (1-HOUR) 1984-1988 |
|---|---|---|---|---|---|
| Skead | 77012 | 17 | 1 | 347 | 149 |
| Hanmer | 77013 | 0 | 1 | 67 | 56 |
| Garson | 77065 | 1 | 1 | 162 | 84 |
| Ash Street | 77016 | 2 | 0 | 81 | 85 |
| Coniston | 77028 | 8 | 1 | 167 | 68 |
| New Sudbury | 77075 | 4 | 0 | 125 | 109 |
| TOTAL | | 32 (89%) | 4 (11%) | 949 (63%) | 551 (37%) |

## TABLE 8

## 1-HOUR, 1-HOUR (CONTROL ORDER), AND 24-HOUR FREQUENCY OF EXCEEDANCES FOR 6 STATIONS FROM 1978 TO 1988

| YEAR | 1-HOUR >0.25 PPM | 1-HOUR (CONTROL ORDER) >0.50 PPM | 24-HOUR >0.10 PPM |
|---|---|---|---|
| 1976 | 404 | 95 | 21 |
| 1977 | 410 | 90 | 18 |
| 1978 | 232 | 33 | 12 |
| 1979 | 147 | 19 | 6 |
| 1980 | 211 | 20 | 4 |
| 1981 | 134 | 21 | 5 |
| 1982 | 84 | 11 | 1 |
| 1983 | 141 | 21 | 4 |
| 1984 | 121 | 17 | 2 |
| 1985 | 132 | 12 | 0 |
| 1986 | 85 | 7 | 1 |
| 1987 | 143 | 11 | 1 |
| 1988 | 70 | 4 | 0 |

## TABLE 9

## ANNUAL MEAN SULPHATION RATE AND NUMBER OF TIMES OVER THE MONTHLY OBJECTIVE IN SUDBURY FROM 1978 TO 1980

| | | 1978 | | 1979 | | 1980 | | | |
|---|---|---|---|---|---|---|---|---|---|
| STATION NAME | STATION NUMBER | # OF TIMES OVER MONTHLY OBJECTIVE | ANNUAL MEAN SULPHATION RATE | # OF TIMES OVER MONTHLY OBJECTIVE | ANNUAL MEAN SULPHATION RATE | # OF TIMES OVER MONTHLY OBJECTIVE | ANNUAL MEAN SULPHATION RATE | TOTAL # OVER OBJECTIVE | DATE OF MAXIMUM & MAXIMUM |
| Ash Street | 77015 | 3 | .62 | 6 | .74 | 3 | 1.03** | 12 | 07/80 - 2.32 |
| Lisgar Street | 77026 | 4 | .52 | 3 | .51 | 1 | .82*** | 8 | 07/80 - 1.54 |
| Auger Avenue | 77030 | 0 | .38 | 1 | .36 | 1 | .60*** | 2 | 07/80 - 1.16 |
| Williams Avenue | 77034 | 0 | .29 | 0 | .29 | 1 | .51* | 1 | 07/80 - .96 |
| LaForest Avenue | 77036 | 2 | .44 | 1 | .44 | 2 | .68* | 5 | 07/80 - 1.61 |
| Marion Street | 77037 | 0 | .32 | 0 | .24 | 2 | .59* | 2 | 06/80 - .89 |
| Kirkland/Ramsey | 77038 | 1 | .29 | 0 | .27 | 0 | .34* | 1 | 01/78 - .75 |
| Southview Drive | 77039 | 1 | .38 | 0 | .28 | 1 | .45* | 2 | 06/80 - .87 |
| Tuddenham Avenue | 77040 | 1 | .39 | 0 | .32 | 0 | .43* | 1 | 01/78 - .72 |
| Second Avenue | 77041 | 0 | .30 | 0 | .26 | 0 | .33** | 0 | 01/78 - .62 |
| Oliver Street | 77043 | 1 | .39 | 1 | .34 | 1 | .42* | 3 | 05/78 - 1.29 |

* Operated for 5 months
** Operated for 6 months
*** Operated for 4 months

## TABLE 10

## TOTAL NITROGEN OXIDES (NOX), NITRIC OXIDE (NO) AND NITROGEN DIOXIDE ($NO_2$)

### 1-HOUR MAXIMUM (PPM)

| STATION | CONTAMINANT | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | NOX | .32 | .51 | .35 | .60 | .56 | .29 | .31 | .26 | - | - | - |
| | NO | .27 | .26 | .42 | .49 | .46 | .39 | .38 | .24 | - | - | - |
| | $NO_2$ | .09 | .07 | .08 | .08 | .10 | .06 | .43* | .06 | - | - | - |
| Science North | NOX | - | - | - | - | - | - | .49 | .48 | .30 | .49 | .30 |
| | NO | - | - | - | - | - | - | .48 | .42 | .25 | .41 | .24 |
| | $NO_2$ | - | - | - | - | - | - | .12 | .09 | .07 | .12 | .17 |

* There were 3 exceedances of the 1-hour objective (0.20 PPM)

### 24-HOUR MAXIMUM (PPM)

| STATION | CONTAMINANT | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | NOX | .15 | .12 | .11 | .10 | .10 | .05 | .04 | .05 | - | - | - |
| | NO | .10 | .11 | .09 | .07 | .08 | .12 | .10 | .04 | - | - | - |
| | $NO_2$ | .05 | .04 | .03 | .03 | .03 | .03 | .06 | .02 | - | - | - |
| Science North | NOX | - | - | - | - | - | - | .12 | .12 | .12 | .12 | .07 |
| | NO | - | - | - | - | - | - | .10 | .09 | .09 | .08 | .05 |
| | $NO_2$ | - | - | - | - | - | - | .03 | .04 | .03 | .04 | .03 |

NOTE: There were no exceedances of the 24-hour objective (0.10 PPM)

### ANNUAL ARITHMETIC MEAN (PPM)

| STATION | CONTAMINANT | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | NOX | .019 | .012 | .011 | .013 | .012 | .010 | .009 | .017 | - | - | - |
| | NO | .007 | .006 | .005 | .006 | .007 | .005 | .007 | .010 | - | - | - |
| | $NO_2$ | .012 | .006 | .006 | .007 | .006 | .006 | .006 | .007 | - | - | - |
| Science North | NOX | - | - | - | - | - | - | .024 | .016 | .018 | .019 | .015 |
| | NO | - | - | - | - | - | - | .014 | .008 | .008 | .008 | .005 |
| | $NO_2$ | - | - | - | - | - | - | .010 | .010 | .010 | .010 | .010 |

## TABLE 11

## TOTAL REDUCED SULPHUR (TRS) IN PPB

| STATION | NUMBER OF EXCEEDANCES | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Science North (77203) | 24-Hour Objective | - | - | - | - | - | - | 0(1) | 0(4) | 0(5) | 0(2) | 0(2) |
| | 1-Hour Objective | - | - | - | - | - | - | 0(5) | 0(5) | 0(6) | 0(10) | 0(9) |

() - Indicates the maximum
Provincial Objective: 27 PPB (1-Hour and 24-Hour)

### ANNUAL ARITHMETIC MEAN (PPB)

| STATION | STATION NUMBER | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Science North | 77203 | - | - | - | - | - | - | 0.0 | 0.7 | 0.3 | 0.4 | 0.3 |

## TABLE 12

## CARBON MONOXIDE (CO) IN PPM

### NUMBER OVER THE 1-HOUR OBJECTIVE AND 8-HOUR OBJECTIVE

| STATION | NUMBER OF EXCEEDANCES | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street (77016) | 1-Hour Objective | 0(6) | 0(11) | 0(14) | 0(8) | 0(7) | 0(8) | 0(8) | 0(8) | 0(8) | 0(7) | - |
| | 8-Hour Objective | 0(4) | 0(5) | 0(4) | 0(4) | 0(4) | 0(7) | 0(5) | 0(6) | 0(5) | 0(2) | - |
| Science North (77203) | 1-Hour Objective | - | - | - | - | - | - | 0(14) | 0(12) | 0(6) | 0(5) | 0(3) |
| | 8-Hour Objective | - | - | - | - | - | - | 0(6) | 0(3) | 0(4) | 0(2) | 0(3) |

() - Indicates maximum
Provincial Objective: 1-Hour (30 PPM) and 8-Hour (13 PPM)

### ANNUAL ARITHMETIC MEAN (PPM)

| STATION | STATION NUMBER | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | 77016 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | - |
| Science North | 77203 | - | - | - | - | - | - | 0.7 | 0.4 | 0.6 | 0.5 | 0.4 |

# TABLE 13

## OZONE ($O_3$) IN PPB

### 1-HOUR MAXIMUM (PPB)

| STATION | STATION NUMBER | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | 77016 | 118 | 96 | 78 | 79 | 99 | 70 | 70 | 83 | 88 | 89 | 84 |
| Science North | 77203 | - | - | - | - | - | - | 88 | 117 | 104 | 89 | 113 |

### NUMBER OF TIMES OVER 80 (PPB) - 1-HOUR AVERAGE

| STATION | STATION NUMBER | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | 77016 | 44 | 23 | 0 | 0 | 9 | 0 | 0 | 1 | 2 | 6 | 3* |
| Science North | 77203 | - | - | - | - | - | - | 9 | 45 | 8 | 5 | 91 |

### ANNUAL ARITHMETIC MEAN (PPB)

| STATION | STATION NUMBER | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | 77016 | 18.0 | 18.3 | 13.9 | 15.6 | 16.0 | 14.2 | 15.8 | 13.4 | 17.1 | 19.4 | 22.2* |
| Science North | 77203 | - | - | - | - | - | - | 23.6 | 28.3 | 25.2 | 25.8 | 29.5 |

*Data for 6 months (January to June)

## TABLE 14

### ANNUAL MEAN DUSTFALL LEVELS (G/M$^2$/30 DAYS) IN SUDBURY 1978-1988

| STATION | STATION NUMBER | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ash Street | 77016 | 2.4 | 2.6 | 3.1 | 2.5 | 4.6 | 5.8 | * | 5.0 | 2.9 | 1.1 | * | Discontinued 05/88 |
| Lisgar Street | 77026 | 3.7 | 3.3 | 4.2 | * | - | - | - | - | - | - | - | Discontinued 11/84 |
| Auger Avenue | 77030 | 2.8 | * | - | - | - | - | - | - | - | - | - | Discontinued 11/83 |
| Southview Drive | 77039 | 2.1 | 2.6 | 3.2 | 2.6 | 2.7 | 6.9 | * | - | - | - | - | Discontinued 11/84 |
| Tuddenham Avenue | 77040 | 4.4 | 4.4 | 6.0 | - | - | - | - | - | - | - | - | Discontinued 12/80 |
| Second Avenue | 77041 | 5.4 | 4.8 | 5.0 | - | - | - | - | - | - | - | - | Discontinued 11/80 |
| Oliver Street | 77043 | 4.8 | 6.2 | 5.2 | 4.4 | 4.4 | 6.2 | * | 4.5 | 3.6 | 4.0 | * | Discontinued 05/88 |
| Penman Avenue | 77049 | 3.4 | 3.5 | 8.6 | - | - | - | - | - | - | - | - | Discontinued 12/80 |
| Highway 17 West | 77051 | 3.3 | 3.6 | 4.1 | 4.6 | 3.1 | 5.7 | * | - | - | - | - | Discontinued 11/84 |
| Glover Street | 77078 | 5.7 | * | - | - | - | - | - | - | - | - | - | Discontinued 06/79 |
| Kelly Lake Road | 77082 | 2.6 | * | - | - | - | - | - | - | - | - | - | Discontinued 02/79 |
| Southview/Ind. E | 77083 | 3.7 | 3.5 | 4.3 | 3.9 | 3.6 | 6.9 | * | - | - | - | - | Discontinued 11/84 |
| Junc. Cr./Ind. W | 77084 | 3.5 | * | - | - | - | - | - | - | - | - | - | Discontinued 02/79 |
| Falconbridge Hwy | 77089 | 4.2 | 3.9 | 4.5 | - | - | - | - | - | - | - | - | Discontinued 12/80 |
| Old Falconb. Hwy | 77200 | - | - | - | * | 2.7 | 2.0 | * | - | - | - | - | Discontinued 11/84 |
| Travers Street | 77211 | - | - | - | - | - | - | - | - | * | 2.7 | 2.2 | Continues to Operate |

* - Insufficient number of monthly values to calculate annual mean.

Annual Objective: 4.6 grams/metre$^2$/30 days.

## TABLE 15

## SUMMARY OF TOTAL SUSPENDED PARTICULATE DATA COLLECTED IN THE SUDBURY AREA FROM 1978 TO 1988

| STATION | STATION NUMBER | NUMBER OF SAMPLES COLLECTED | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Ash Street | 77016 | 80 | 67 | 51 | 56 | 56 | 52 | 84 | 54 | 55 | 56 | 56 |
| Lisgar Street | 77026 | 53 | 59 | 49 | 44 | 44 | 52 | 36 | 54 | 51 | 53 | 54 |
| Copper Cliff | 77070 | 63 | 53 | 53 | 53 | 55 | 54 | 51 | 55 | 60 | 55 | 59 |
| Falconbridge | 77076 | 72 | 57 | 46 | 47 | 43 | 49 | 2 | 19 | - | - | - |

| STATION | STATION NUMBER | MAXIMUM 24-HOUR VALUE (ug/m³) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Ash Street | 77016 | 171 | 153 | 102 | 98 | 117 | 82 | 101 | 154 | 72 | 205 | 94 |
| Lisgar Street | 77026 | 156 | 108 | 161 | 174 | 120 | 153 | 91 | 71 | 98 | 235 | 109 |
| Copper Cliff | 77070 | 170 | 174 | 206 | 118 | 426 | 142 | 292 | 72 | 84 | 357 | 124 |
| Falconbridge | 77076 | 217 | 201 | 343 | 139 | 135 | 125 | 18 | 59 | - | - | - |

| STATION | STATION NUMBER | ANNUAL GEOMETRIC MEAN (ug/m³) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Ash Street | 77016 | 32 | 37 | 42 | 40 | 34 | 28 | 28 | 26 | 29 | 31 | 25 |
| Lisgar Street | 77026 | 48 | 51 | 54 | 43 | 35 | 40 | 34 | 31 | 32 | 35 | 30 |
| Copper Cliff | 77070 | 37 | 39 | 55 | 47 | 41 | 38 | 42 | 29 | 31 | 33 | 31 |
| Falconbridge | 77076 | 42 | 40 | 56 | 37 | 37 | 33 | 15 | 26 | - | - | - |

| STATION | STATION NUMBER | NUMBER OF SAMPLES ABOVE PROVINCIAL 24-HOUR OBJECTIVE* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Ash Street | 77016 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Lisgar Street | 77026 | 4 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 0 |
| Copper Cliff | 77070 | 1 | 2 | 4 | 0 | 2 | 1 | 4 | 0 | 0 | 2 | 1 |
| Falconbridge | 77076 | 4 | 4 | 7 | 1 | 1 | 1 | 0 | 0 | - | - | - |

* Provincial Objective: Annual - 60 ug/m³ (Geometric Mean)
24-Hour - 120 ug/m³

## TABLE 16

## ANNUAL GEOMETRIC MEAN FOR METALS IN TOTAL SUSPENDED PARTICULATE COLLECTED IN THE SUDBURY AREA FROM 1978 TO 1988

| ELEMENT | LOCATION | ANNUAL GEOMETRIC MEAN | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Iron *($Fe_2O_2$) | Ash Street | 2.6 | 0.9 | 1.3 | 1.4 | 1.0 | 1.0 | 0.7 | 0.9 | 0.3 | 1.3 | 1.0 |
| | Lisgar Street | 1.4 | 1.3 | 1.9 | 1.4 | 1.0 | 1.3 | 1.1 | 1.1 | 1.0 | 1.1 | 1.1 |
| | Copper Cliff | 1.6 | 1.4 | 2.1 | 2.1 | 2.0 | 1.7 | 1.9 | 1.3 | 1.6 | 1.6 | 1.3 |
| | Falconbridge | 1.7 | 1.1 | 1.4 | 0.9 | 0.9 | 1.0 | - | 1.1 | - | - | - |
| Nickel (Ni) | Ash Street | .02 | .03 | .07 | .06 | .02 | .02 | .03 | .07 | .05 | .06 | .09 |
| | Lisgar Street | .03 | .02 | .07 | .05 | .02 | .02 | .03 | .05 | .06 | .04 | .07 |
| | Copper Cliff | .10 | .07 | .33 | .24 | .03 | .08 | .06 | .17 | .20 | .16 | .19 |
| | Falconbridge | .05 | .04 | .07 | .03 | .02 | .03 | .03 | .01 | - | - | - |
| Copper (Cu) | Ash Street | .18 | .33 | .48 | .24 | .24 | .39 | .30 | .37 | .36 | .32 | .23 |
| | Lisgar Street | .26 | .20 | .22 | .27 | .33 | .22 | .27 | .15 | .22 | .17 | .10 |
| | Copper Cliff | .60 | .28 | .70 | .54 | .25 | .40 | .41 | .36 | .46 | .36 | .22 |
| | Falconbridge | .22 | .17 | .40 | .31 | .37 | .24 | .11 | .10 | - | - | - |

* Iron is expressed as $Fe_2O_3$

## TABLE 17

## MAXIMUM 24-HOUR VALUES FOR METALS IN SUSPENDED PARTICULATE COLLECTED IN THE SUDBURY AREA FROM 1978 TO 1988

| ELEMENT | LOCATION | MAXIMUM 24-HOUR VALUE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Iron *(Fe$_2$O$_3$) | Ash Street | 15.4 | 10.0 | 15.2 | 5.3 | 19.9 | 6.9 | 11.2 | 13.3 | 9.0 | 46.2 | 10.6 |
| | Lisgar Street | 14.4 | 7.0 | 8.1 | 11.3 | 20.4 | 7.3 | 11.9 | 11.9 | 3.9 | 42.3 | 10.0 |
| | Copper Cliff | 13.4 | 28.2 | 18.0 | 13.2 | 22.2 | 10.3 | 9.7 | 9.6 | 12.0 | - | 9.0 |
| | Falconbridge | 9.6 | 8.3 | 16.4 | 6.4 | 8.7 | 6.9 | 1.0 | 2.6 | - | - | - |
| Nickel (Ni) | Ash Street | 0.73 | 1.10 | 1.69 | 0.38 | 1.70 | 0.57 | 0.53 | .73 | .73 | 0.84 | 1.73 |
| | Lisgar Street | .44 | .23 | .65 | .46 | .80 | .67 | .38 | 1.28 | .41 | .04 | .91 |
| | Copper Cliff | 1.76 | 1.93 | 4.41 | 1.50 | 1.17 | 0.92 | 0.59 | 1.37 | 2.29 | .77 | 6.14 |
| | Falconbridge | .78 | .31 | .55 | .21 | .25 | .29 | .09 | .55 | - | - | - |
| Copper (Cu) | Ash Street | 2.29 | 2.42 | 1.69 | 1.50 | 1.67 | 1.60 | 2.26 | 1.39 | 1.40 | 2.12 | 1.11 |
| | Lisgar Street | 2.25 | 1.44 | .86 | .80 | 1.11 | 1.05 | 1.40 | .67 | .91 | 1.58 | .53 |
| | Copper Cliff | 8.16 | 1.85 | 10.31 | 2.50 | 1.37 | 2.92 | 2.26 | 1.83 | 9.86 | .76 | 1.62 |
| | Falconbridge | 1.67 | .73 | 1.71 | 1.30 | 1.72 | .93 | 0.13 | .25 | - | - | - |

* Iron is expressed as Fe$_2$O$_3$

## TABLE 18

## SOILING INDEX (COH/1000 FEET) IN SUDBURY FROM 1978 TO 1988

| STATION | STATION NUMBER | ANNUAL ARITHMETIC MEAN (IN COH UNITS) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Ash Street | 77016 | .13 | .12 | .13 | .12 | .12 | .12 | .15 | .13 | .16 | .16 | .15 |
| Coniston | 77028 | .16 | .15 | .14 | .15 | .18 | .12 | .18 | .17 | .12 | .14 | .12 |
| New Sudbury | 77075 | .13 | .14 | .11 | .17 | .17 | .15 | .15 | .17 | .15 | .15 | .14 |
| Lisgar Street | 77026 | .19 | .17 | .17 | - | - | - | - | - | - | - | - |
| Science North | 77203 | - | - | - | - | - | - | .31 | .19 | .22 | .26 | .21 |

| STATION | STATION NUMBER | 24-HOUR MAXIMUM (IN COH UNITS) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lisgar Street | 77026 | 1.0 | 0.6 | 0.7 | - | - | - | - | - | - | - | - |
| Ash Street | 77016 | 0.9 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.8 | 0.5 |
| Coniston | 77028 | 0.8 | 0.7 | 0.8 | 0.7 | 0.7 | 0.9 | 1.2 | 0.9 | 0.5 | 0.6 | 0.4 |
| New Sudbury | 77075 | 0.5 | 0.8 | 0.6 | 0.7 | 0.9 | 1.2 | 0.9 | 0.9 | 0.6 | 0.8 | 0.6 |
| Science North | 77203 | - | - | - | - | - | - | 1.3 | 1.2 | 1.0 | 1.4 | 0.8 |

| STATION | STATION NUMBER | NUMBER OF TIMES OVER 1.0 COH UNITS - 24-HOUR AVERAGE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Lisgar Street | 77026 | 0 | 0 | 0 | - | - | - | - | - | - | - | - |
| Ash Street | 77016 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coniston | 77028 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| New Sudbury | 77075 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Science North | 77203 | - | - | - | - | - | - | 1 | 1 | 0 | 2 | 0 |

# TABLE 19

## SUMMARY OF THE AIR POLLUTION INDEX

## 1978-1988

| | ASH STREET (77016) | | | | CONISTON (77028) | | | | NEW SUDBURY (77075) | | | | SCIENCE NORTH (77203) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MAXIMUM INDEX | # OF TIMES | | ANNUAL MEAN | MAXIMUM INDEX | # OF TIMES | | ANNUAL MEAN | MAXIMUM INDEX | # OF TIMES | | ANNUAL MEAN | MAXIMUM INDEX | # OF TIMES | | ANNUAL MEAN |
| YEAR | | ≥32 | ≥50 | | | ≥32 | ≥50 | | | ≥32 | ≥50 | | | ≥32 | ≥50 | |
| 1978 | 31 | 0 | 0 | 4.5 | 34 | 3 | 0 | 5.1 | 42 | 1 | 0 | 4.8 | STARTED JUNE 1988 | | | |
| 1979 | 18 | 0 | 0 | 4.5 | 31 | 0 | 0 | 4.5 | 28 | 0 | 0 | 4.5 | | | | |
| 1980 | 23 | 0 | 0 | 5.4 | 30 | 0 | 0 | 5.2 | 24 | 0 | 0 | 4.4 | | | | |
| 1981 | 21 | 0 | 0 | 3.9 | 20 | 0 | 0 | 4.6 | 22 | 0 | 0 | 4.3 | | | | |
| 1982 | 15 | 0 | 0 | 4.0 | 39 | 1 | 0 | 3.8 | 29 | 0 | 0 | 4.3 | | | | |
| 1983 | 39 | 1 | 0 | 3.7 | 19 | 0 | 0 | 3.1 | 63 | 1 | 1 | 3.8 | | | | |
| 1984 | 23 | 0 | 0 | 4.3 | 29 | 0 | 0 | 4.5 | 23 | 0 | 0 | 4.3 | | | | |
| 1985 | 31 | 0 | 0 | 3.9 | 19 | 0 | 0 | 4.0 | 31 | 0 | 0 | 4.4 | | | | |
| 1986 | 23 | 0 | 0 | 4.1 | 18 | 0 | 0 | 3.1 | 20 | 0 | 0 | 4.1 | | | | |
| 1987 | 26 | 0 | 0 | 4.3 | 23 | 0 | 0 | 3.6 | 22 | 0 | 0 | 4.1 | | | | |
| 1988 | 24 | 0 | 0 | 3.5 | 21 | 0 | 0 | 3.8 | 21 | 0 | 0 | 3.6 | 25 | 0 | 0 | 7.5 |
| | Jan. 22, 1983 - 17 Hours | | | | Feb. 7/78, 3 exceedances totalled 23 hours<br>Feb. 5/82 - 20 Hours | | | | Feb. 2/78 - 20 Hours<br>Jan.22/83 - ≥32 - 25 Hours<br>Jan.22/83 - ≥50 - 20 Hours | | | | | | | |

## TABLE 20

## AIR QUALITY INDEX POLLUTANTS AND THEIR IMPACT

| INDEX | CATEGORY | CARBON MONOXIDE CO | NITROGEN DIOXIDE $NO_2$ | OZONE $O_3$ | SULPHUR DIOXIDE $SO_2$ | SUSPENDED PARTICLES SP | $SO_2$ + SP (AS MEASURED BY THE API) | TOTAL REDUCED SULPHUR TRS |
|---|---|---|---|---|---|---|---|---|
| 100-Over | Very poor | Increasing cardiovascular symptoms in non-smokers with heart disease, some visual impairment | Increasing sensitivity of patients with asthma and bronchitis | Light exercise produces respiratory effects in patients with chronic pulmonary disease | Increasing sensitivity in patients with asthma and bronchitis | Increasing sensitivity in patients with asthma and bronchitis | Significant respiratory effects in patients with asthma and bronchitis | Sensitive individuals may suffer nausea and headaches due to severe odour |
| 50-99 | Poor | Increased cardiovascular symptoms in smokers with heart disease | Odour and discolouration. Some increase in bronchial reactivity in asthmatics | Decreasing performance by athletes exercising heavily | Odorous increasing vegetation damage | Visibility decreased, soiling evident | Increased symptoms in patients with chronic respiratory disease | Extremely odorous |
| 32-49 | Moderate | Blood chemistry, but no detectable impairment | Odorous | Injurious to many vegetation species, e.g., white beans, tomatoes, etc. | Injurious to some species of vegetation | Some decrease in visibility | Injurious to vegetation due to sulphur dioxide | Odorous |
| 16-31 | Good | No effects | Slight odour | Injurious to some vegetation species in combination with $SO_2$ (4 hours) | Injurious to some vegetation species in combination with ozone (4 hours) | No effects | No effects | Slight odours |
| 0-15 | Very good | No effects | No effects | No effects | No effects | No effects | No effects | No effects |

## TABLE 21

## AIR QUALITY INDEX SUMMARY - JUNE TO DECEMBER 1988

| | | NUMBER OF HOURS AQI IN RANGE | | | | | NUMBER OF HOURS POLLUTANT RESPONSIBLE FOR AQI ≥32 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATION ID # | STATION NAME | VERY GOOD 0-15 | GOOD 16-31 | MODERATE 32-49 | POOR 50-99 | VERY POOR 100+ | $SO_2$ | SP | $O_3$ | TRS | CO | API | $NO_2$ |
| 77203 | Science North | 4383 | 584 | 83 | 16 | 0 | 17 | 0 | 82 | 0 | 0 | 0 | 0 |

# APPENDICES

# APPENDIX A

## Method for Measuring Sulphur Dioxide ($SO_2$) Using the Pulsed Fluorescent Monitor

The pulsed fluorescent sulphur dioxide ($SO_2$) monitor operates on the principle that $SO_2$ molecules excited by ultraviolet light give off radiation.

Pulsating ultraviolet light is focused through a narrow filter into the fluorescent chamber. Here it excites $SO_2$ molecules which give off their characteristic decay radiation. A second filter allows only this radiation to fall on a photomultiplier tube. Electronic signal processing transfers the light energy impinging on the photomultiplier into a voltage which is in direct proportion to the concentration of $SO_2$ in the sample stream being analyzed.

More specifically, light in the 230 nm-190 nm region is used because it exhibits minimal interference by air and most other molecules that are found in ambient air. The pulsed light source emits ultraviolet radiation which acts on the $SO_2$ in the sample gas producing electronically excited $SO_2$. The electronically excited $SO_2$ can then decay back to the ground state by fluorescence. The following equation outlines the overall reaction where $SO_2$ is excited $SO_2$*, $k_f$ is a rate constant and hv refers to the energy released by the reaction.

$$SO_2{*} \xrightarrow{k_f} SO_2 + hv_2$$

The fluorescent radiation impinging upon a detector is directly proportional to the concentration of $SO_2$, thus forming the basis for this measurement technique.

# APPENDIX B

## Method for Measuring Sulphation Rate

## Using the Lead Peroxide ($PbO_2$) Plates

Sulphation rate is measured by exposing small plastic plates coated with lead peroxide ($PbO_2$) to the atmosphere for 30-day periods. The $PbO_2$ reacts with gaseous sulphur dioxide to form lead sulphate. The quantity of sulphate formed is analytically determined and reported as milligrams of sulphur trioxide ($SO_3$) per hundred square centimetres of exposed $PbO_2$ impregnated material per day (mg $SO_3$/100 $cm^2$/day). The method is normally used to detect the presence of sulphur dioxide, but other reactive sulphur compounds, such as $H_2S$ may also be converted to the sulphate form.

The Provincial criterion for sulphation, outlined in Ontario Regulation 296, is 0.7 mg $SO_3$/100 $cm^2$/day for a 30-day exposure.

# APPENDIX C

## Method For the Continuous Sampling and Determination of Nitrogen Dioxide and Nitric Oxide in Ambient Air by Chemiluminescence

The chemiluminescent method is based on the principle that nitric oxide (NO) and ozone ($O_3$) react to produce electronically excited nitrogen dioxide ($NO_2$) which emits light between 600 nm and 2500 nm.

A sample of ambient air is mixed with ozone in a reaction chamber and any NO in the sample reacts with the $O_3$ instantaneously to produce light. Under conditions of excess ozone, the light produced is proportional to the concentration of nitric oxide and is detected by a photomultiplier tube. The resulting current is amplified, and displayed in terms of the nitric oxide concentration.

For the measurement of nitrogen dioxide, the sample stream is diverted through a catalytic converter where nitrogen dioxide is reduced to nitric oxide. The latter subsequently undergoes the reaction described above together with the nitric oxide originally present in the sample. Concentrations of nitrogen dioxide are determined from the differences between signals obtained when the sample is passed through the reaction chamber directly and when the sample is diverted through the catalytic converter.

The normal working range for field instruments is 0-1 parts per million (ppm) by volume, or 0-1300 ug/m³ for NO and 0-2000 ug/m³ for $NO_2$, at 25°C and 101.3 kPa.

The detection limit for both NO and $NO_2$ by this method is 0.002 ppm or about 2.5 ug/m³ for NO and 4.0 ug/m³ for $NO_2$ at 25°C and 101.3 kPa.

# APPENDIX D

## Method for the Continuous Sampling and Determination of Total Reduced Sulphur Compounds (TRS) in Ambient Air by the Principle of Fluorescence

Ambient air is drawn through a scrubber where any sulphur dioxide ($SO_2$) is removed. The sample then enters an oxidizer where reduced sulphur compounds are oxidized to $SO_2$.

The sample is then passed through a beam of ultra violet (UV) radiation of 190 to 230 nm wavelength. The $SO_2$ molecules will absorb this radiation and re-emit fluorescent radiation of characteristic frequencies.

The fluorescent light is separated from the UV light by narrow bandpass filters and detected by a photomultiplier tube whose output current is proportional to the concentration of sulphur dioxide in the sample. The output signal is processed and displayed on a recorder. The instrument is spanned with hydrogen sulphide $H_2S$. TRS concentrations are read directly from the recorder's chart as $H_2S$.

Normal working ranges for field instruments are 0-0.5, 0-1.0 parts per million (ppm) by volume, or 0-700 $ug/m^3$ as $H_2S$ at 25°C and 101.3 kPa.

# APPENDIX E

## Method for the Sampling and Determination of Carbon Monoxide in Ambient Air by Non-Dispersive Infrared Spectrometry

Energy, from a source emitting radiation in the infrared region, is split into two parallel beams, one passing through a reference compartment and the other passing through a sample compartment. The two beams finally pass the detector which consists of two matched cells each containing carbon monoxide (CO). These two cells are separated by a diaphragm. The carbon monoxide in the detector cells absorbs infrared radiation corresponding to its characteristic frequencies. With a non-absorbing gas in the reference cell, and with no carbon monoxide in the sample cell, the signals from both detectors are balanced electronically. Any carbon monoxide introduced into the sample cell will absorb radiation, which reduces the temperature and pressure in the detector cell and displaces a diaphragm separating the two cells. This displacement is detected electronically and amplified to provide an output signal proportional to the CO concentration.

A range of 0-50 ppm, parts per million by volume (0-58 mg/m$^3$), is suitable for most conditions.

The detection limit is 0.6 mg/m$^3$ (0.5 ppm).

# APPENDIX F

## Method for the Continuous Sampling and Determination of Ozone in Ambient Air by Chemiluminescence

A continuous sample of ambient air is mixed with an excess of ethylene in a reaction chamber. Any ozone in the sample reacts instantaneously with the ethylene emitting visible light (chemiluminescence), with peak emission at 440 nanometers (nm). The light intensity, directly proportional to the ozone concentration, is measured with a photomultiplier tube whose output signal is fed to a recorder. The signal is calibrated so that ozone concentrations are read directly on the recorder.

A suitable working range for field instruments is 0-0.5 ppm (0-1000 $ug/m^3$).

The detection limit (sensitivity) for the measurement of ozone by this method is 0.001 ppm (2 $ug/m^3$).

### Interferences and Limitations

Particulate matter in the sample will scatter the emitted light, and also accumulate in the intake line and on optical surfaces. Particulate matter in the sample is removed with a suitable filter.

The reaction of ozone with ethylene is not subject to interference from any of the common gaseous air pollutants.

Moisture may be a potential interferent and can be removed with a suitable drying system.

## APPENDIX G

## Dustfall Monitoring

Dustfall (total) comprises larger, more visible, particulate matter generally around 100 microns in size which settles out from the atmosphere by gravity. It is measured by exposing an open top plastic jar for approximately 30 days.

The total amount of dustfall is determined by weighing the contents of the jar and expressing the results in $g/m^2/30$ days.

The settleable particulate collected in the dustfall jar can be separated into a soluble and an insoluble fraction for further analysis. The insoluble portion can be examined using an optical microscope to determine the composition of the particulate.

Although this method of sampling can be variable and is dependant on external factors such as wind and the amount of rain and/or snowfall during the sampling period, it is very useful in determining the amount of settleable particulate in the atmosphere.

# APPENDIX H

## Method for Measuring Particulate Matter Using the High Volume Sampling Technique

The high volume (hi-vol) sampling technique determines the mass concentration of suspended airborne particulate ($\leq$100 microns) by drawing a known volume of air through a pre-weighed filter medium. Standard operation of the sampler involves air flow rates from 0.9 to 1.4 $m^3$/minute and the use of a Gelman AE glass fibre filter. The sample is collected over a 24-hour period, midnight to midnight, every one, three or six days. The six-day operating schedule is pre-determined and is consistent throughout Canada and the United States. This six-day sampling is considered to be representative of the average air quality over a year.

Two criteria for desirable air quality exist for total suspended particulate matter. One is 120 ug of suspended particulate per cubic metre of air averaged over a 24-hour period. The other is an annual geometric mean of 60 ug/$m^3$. The 24-hour criterion is based on impaired visibility and adverse health effects (in combination with sulphur dioxide), while the annual criterion is based on public awareness of suspended particulate and subsequent aesthetic effects.

High-volume samples may also be analysed for trace metals and compounds.

# APPENDIX I

## Method For the Measurement of Soiling Index Due to Particulate Matter

Ambient air is drawn through a circular area of filter paper at a known sampling rate for a one hour sampling period. This operation is repeated automatically on fresh areas of paper at equal time periods. The absorbance of the circular spots or stains is measured in comparison with that of the clean paper with a photometer using white light of wavelength from 500-800 nm. For comparison purposes, the absorbance readings are reported in coefficient of haze (COH) units per 1000 linear feet of air sampled.

The soiling index, in terms of coefficient of haze (COH) units, is related to the effect of the sampled atmosphere when it is drawn through a clean white filter paper. One COH unit is defined as that quantity of light scattering by particulate matter which produces an absorbance equivalent of 0.01:

Absorbance = $\log_{10} I_0/I$

$I_0$ = intensity of light passing through the clean filter paper

$I$ = intensity of light passing through the soiled paper

For comparison purposes with similar samples in other areas, COH units are normalized by dividing the absorbance by the volume of sample air expressed in multiples of 1000 linear feet.

Ambient air quality criteria for coefficient of haze outlined in Ontario Regulation 296 are 1.0 COH units per 1000 feet for a 24-hour period and 0.5 COH unit per 1000 feet of air for one year.

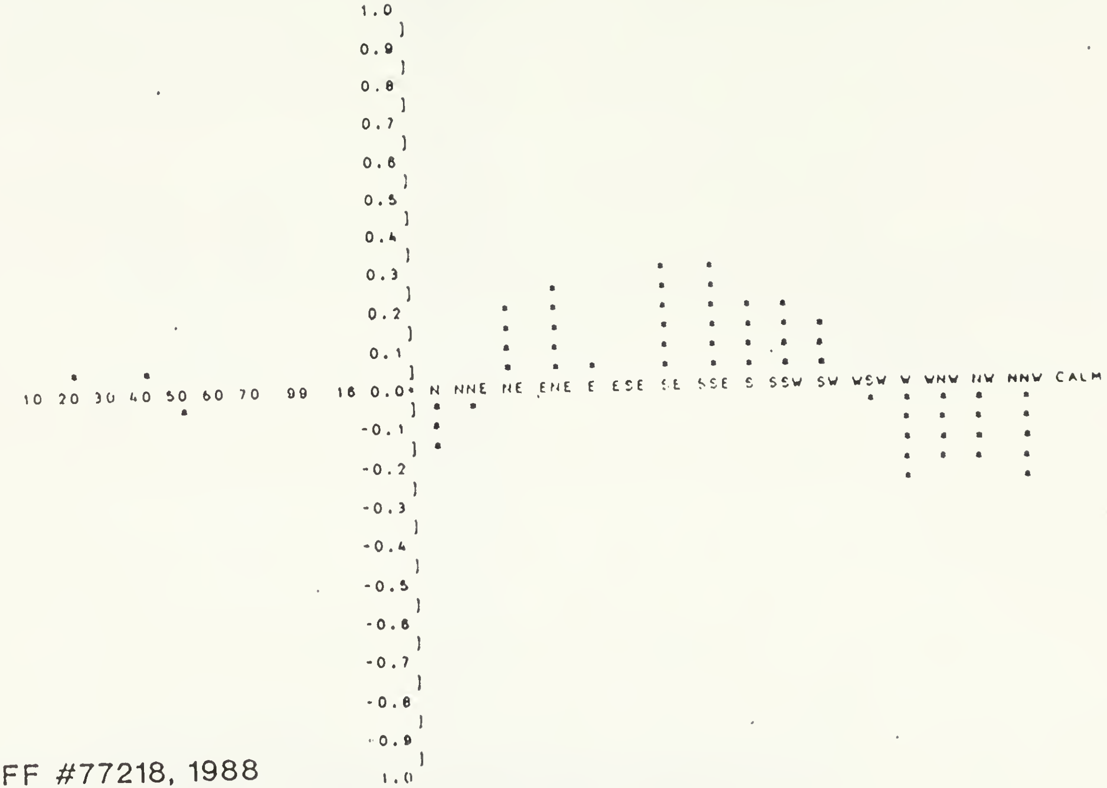
## APPENDIX J

## ONTARIO MINISTRY OF THE ENVIRONMENT

## DESIRABLE AMBIENT AIR QUALITY OBJECTIVES ESTABLISHED FOR ONTARIO

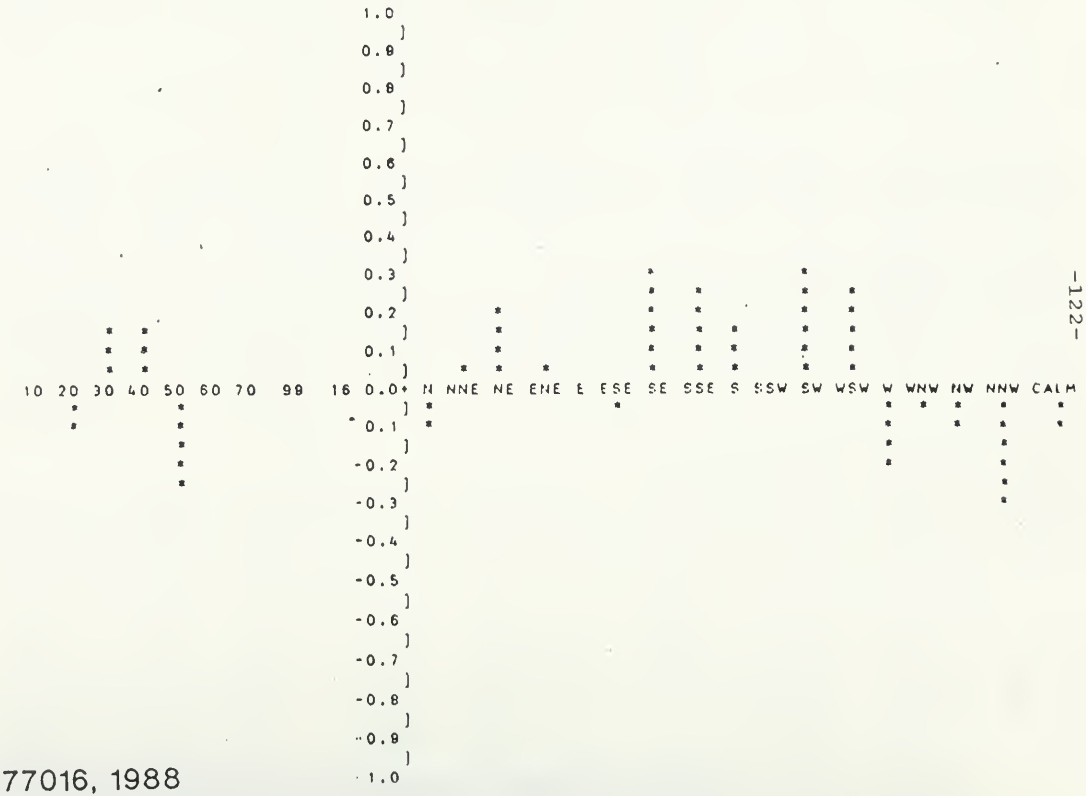
| Parameter | Desirable Ambient Air Quality Objectives | Prime Reasons for Establishing Objectives or Monitoring Parameter |
|---|---|---|
| Carbon Monoxide | 30 ppm averaged for 1 hour | Protection of human health. |
| | 13 ppm averaged for 8 hours | Protection of human health. |
| Dustfall | 7.0 $g/m^2$ in 30 days<br>4.6 $g/m^2$ (mean monthly average in 1 year) | Soiling (in keeping with other control agencies). |
| Nitrogen Dioxide | 0.20 ppm averaged for 1 hour | Protection of human health. |
| | 0.10 ppm averaged for 24 hours | Protection of human health. |
| Suspended Particulates | 120 $ug/m^3$ averaged for 24 hours<br>60 $ug/m^3$ geometric mean for 1 year | Based on health effects in conjunction with elevated levels of $SO_2$ and impairment of visibility. |
| Sulphur Dioxide | 0.25 ppm averaged for 1 hour | Protection of vegetation. |
| | 0.10 ppm averaged for 24 hours | Health effects. In conjunction with soiling index, can impair visibility. |
| | 0.02 ppm averaged over 1 year | Protection of vegetation. |
| TRS - Paper Mills | 0.027 ppm averaged for 1 hour | Protection against offensive odours. |
| Coefficent of Haze | 1.0/1,000 ft. of air - 24 hours<br>0.5/1,000 ft. of air - 1 year | Based on health effects in conjunction with elevated levels of $SO_2$. Used to calculate A.P.I. |
| Ozone | 80 ppb | Protection of sensitive vegetation. |

# APPENDIX K
# HIVOL - WIND CORRELATION ANALYSIS
# POLLUTANT - TOTAL SUSPENDED PARTICULATE



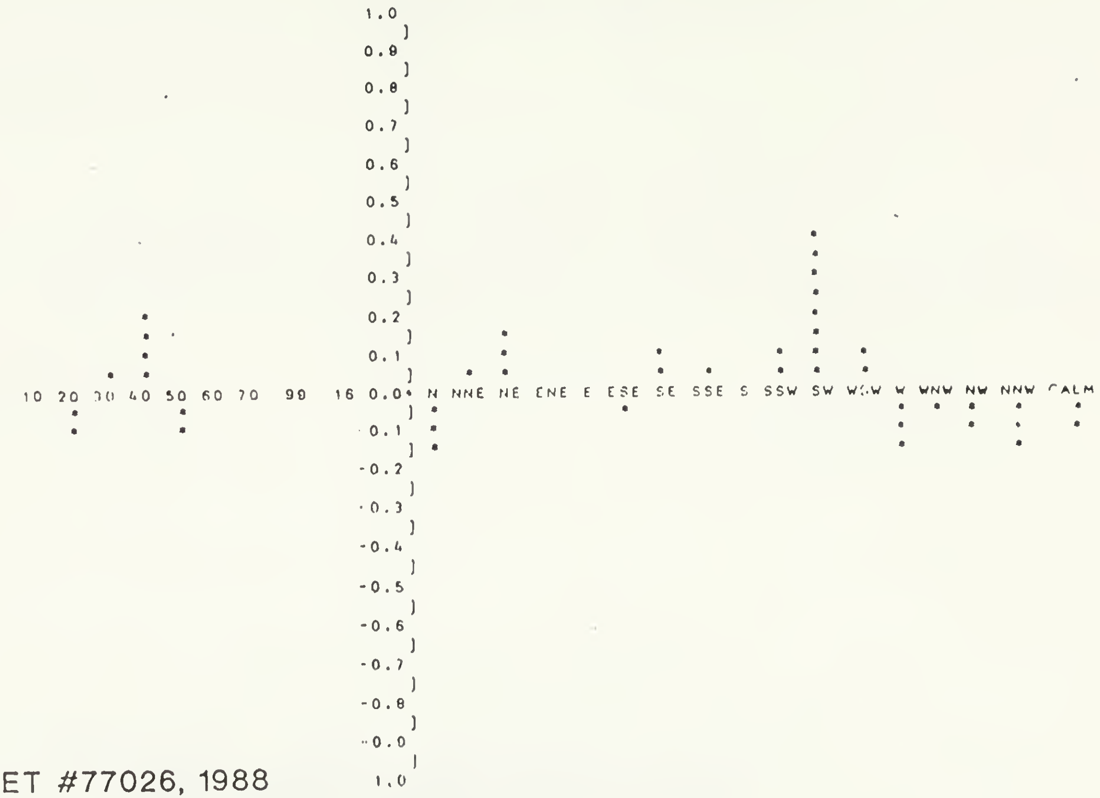
COPPER CLIFF #77218, 1988

# APPENDIX L
## HIVOL - WIND CORRELATION ANALYSIS
## POLLUTANT - TOTAL SUSPENDED PARTICULATE



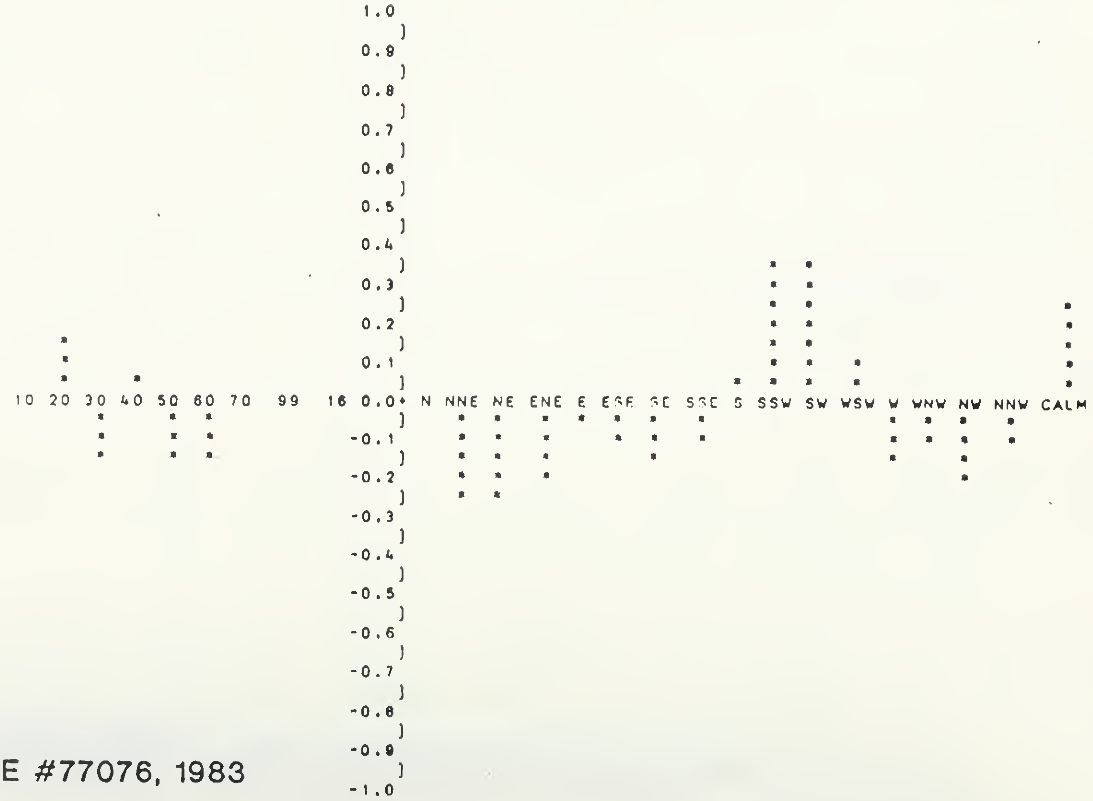
ASH STREET #77016, 1988

# APPENDIX M
# HIVOL - WIND CORRELATION ANALYSIS
# POLLUTANT - TOTAL SUSPENDED PARTICULATE



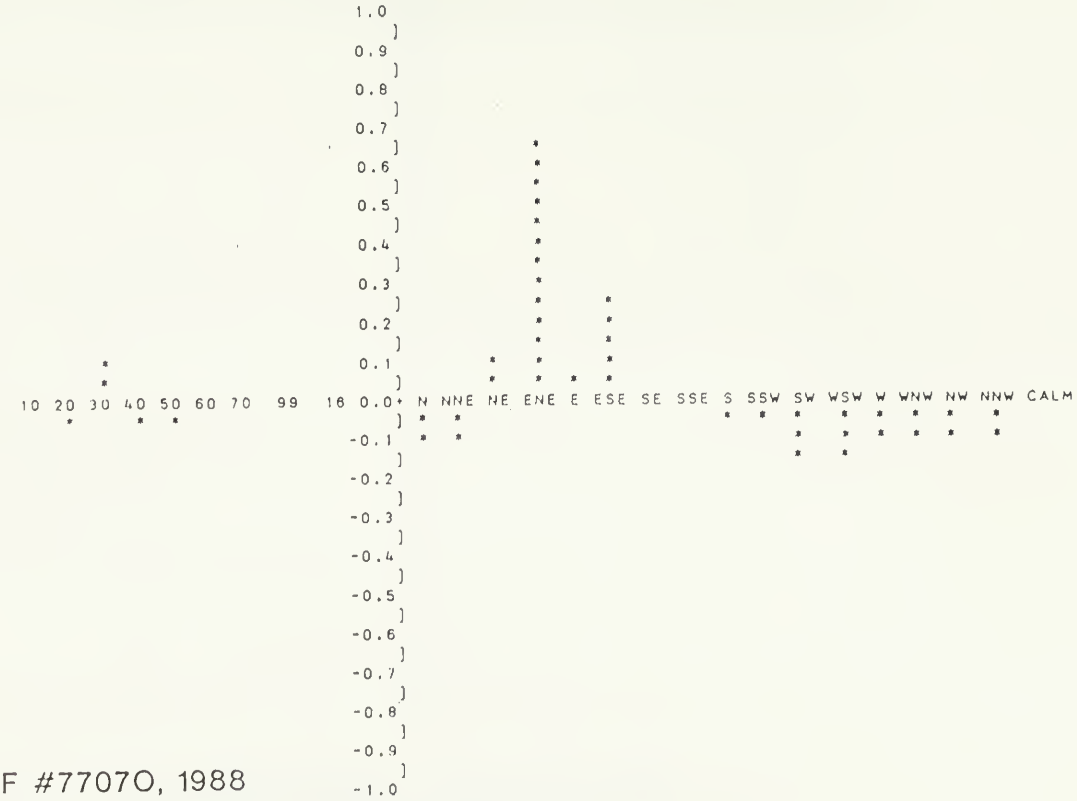
LISGAR STREET #77026, 1988

# APPENDIX N
## HIVOL - WIND CORRELATION ANALYSIS
## POLLUTANT - TOTAL SUSPENDED PARTICULATE



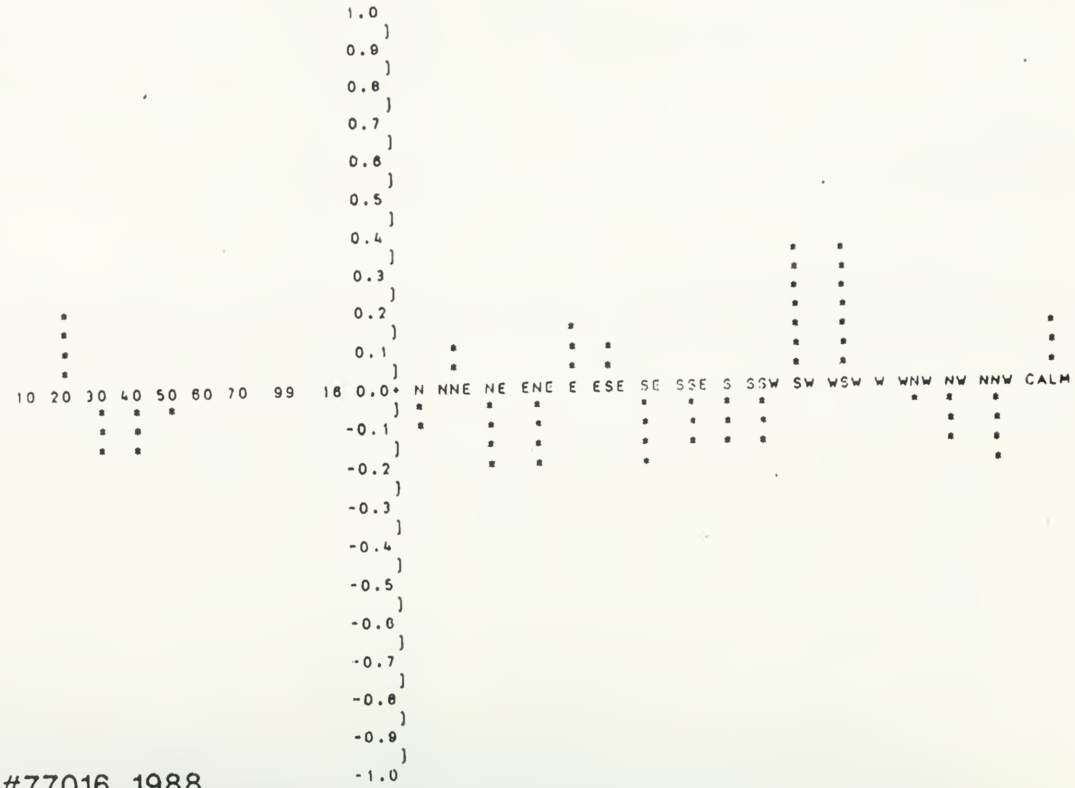
FALCONBRIDGE #77076, 1983

# APPENDIX O
## HIVOL - WIND CORRELATION ANALYSIS
## POLLUTANT - NICKEL IN TSP



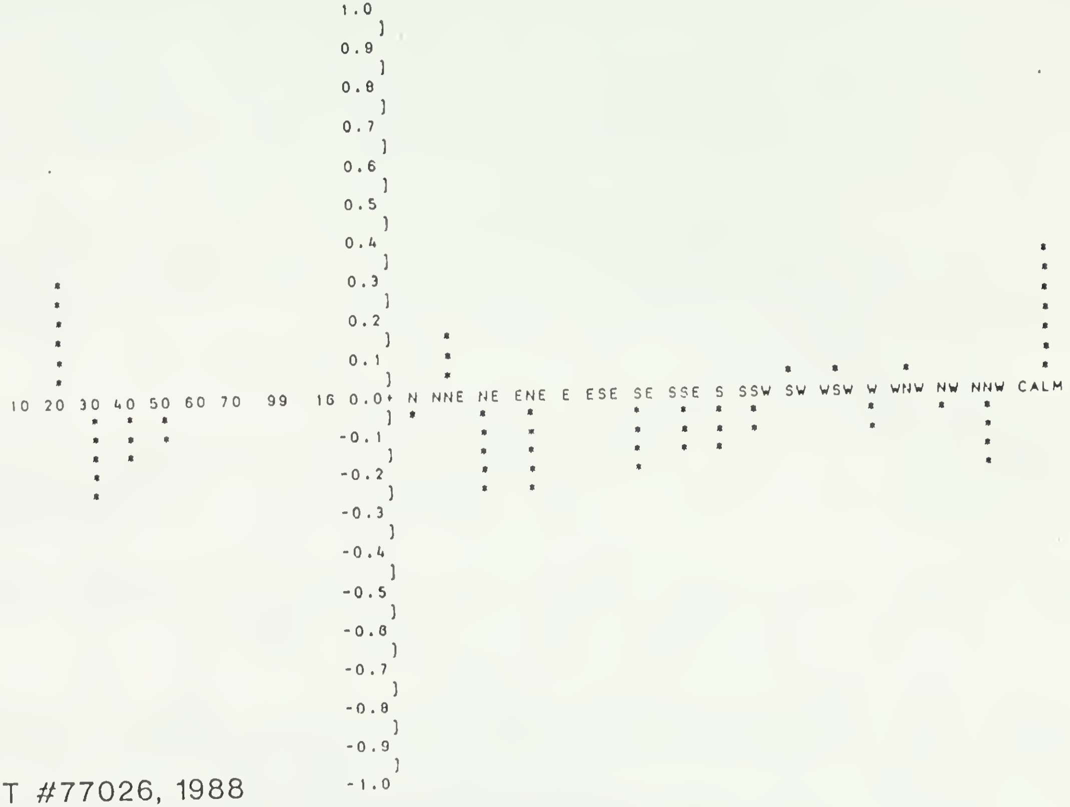
COPPER CLIFF #77070, 1988

# APPENDIX P
## HIVOL - WIND CORRELATION ANALYSIS
## POLLUTANT - NICKEL IN TSP



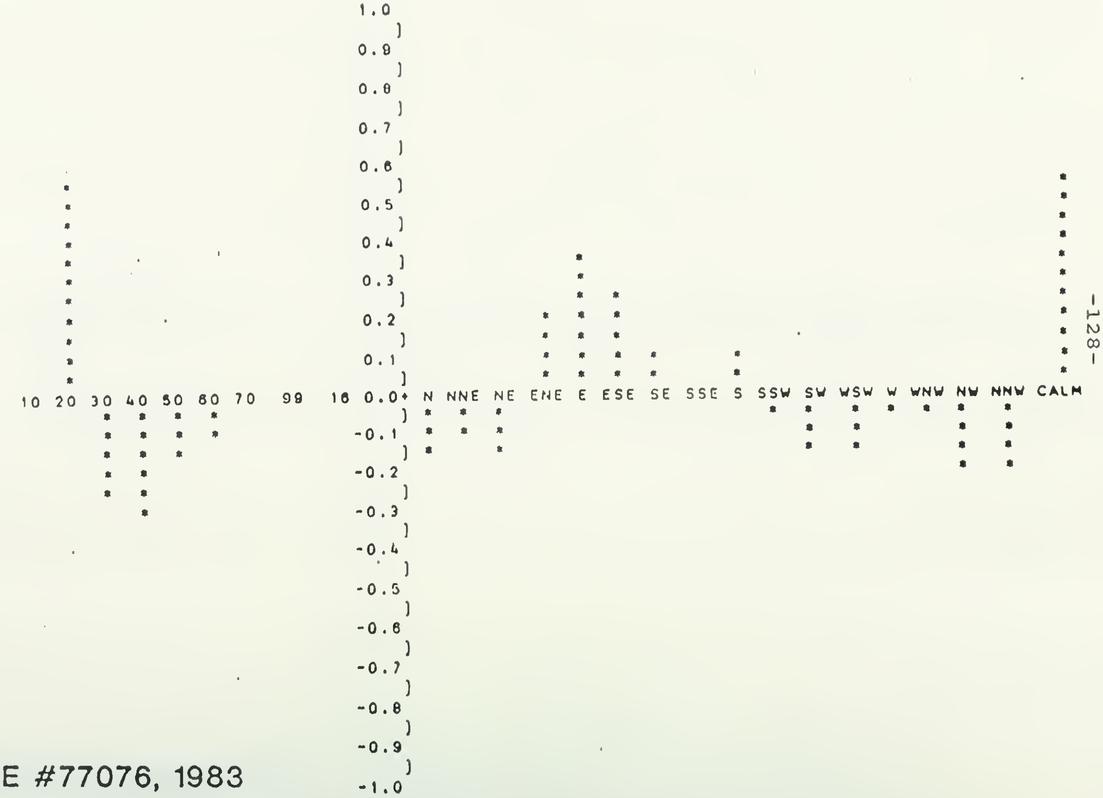
ASH STREET #77016, 1988

# APPENDIX Q
## HIVOL - WIND CORRELATION ANALYSIS
## POLLUTANT - NICKEL IN TSP



LISGAR STREET #77026, 1988

# APPENDIX R
# HIVOL - WIND CORRELATION ANALYSIS
# POLLUTANT - NICKEL IN TSP



FALCONBRIDGE #77076, 1983